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FINAL REPORT

CONTRACT NUMBER NAS 1-430



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National Aeronautics and Space Administration

CONTRACT NUMBER NAS 1-430

JUNE 1961

Submitted by

*Western Electric Company*  
INCORPORATED

220 Church Street N.Y. 13, N.Y.

In association with

BELL TELEPHONE LABORATORIES, INCORPORATED  
THE BENDIX CORPORATION  
BURNS AND ROE, INCORPORATED  
INTERNATIONAL BUSINESS MACHINES CORPORATION

## **FOREWORD**

This is the twenty-first Project Mercury progress report submitted to the National Aeronautics and Space Administration by Western Electric Company, Inc., and its associated Team Members: Bell Telephone Laboratories, Inc.; The Bendix Corporation; Burns and Roe, Inc.; and International Business Machines Corporation. The report has been prepared in accordance with instructions set forth in NASA Specification No. S-45B, dated October 30, 1959.

This report, the final one of this type, reviews highlights of the Western Electric Team's progress from July 1959 through May 1961 and summarizes the total efforts by all Team Members in implementing the tracking and ground instrumentation systems to support the National Aeronautics and Space Administration's manned satellite program.

## TABLE OF CONTENTS

	<i>Page</i>		<i>Page</i>
PART I—Project Management .....	1	PART III—Station Implementation .....	51
PART II—Team Members' Reports .....	11	APPENDIX—List of Abbreviations .....	65

## LIST OF ILLUSTRATIONS

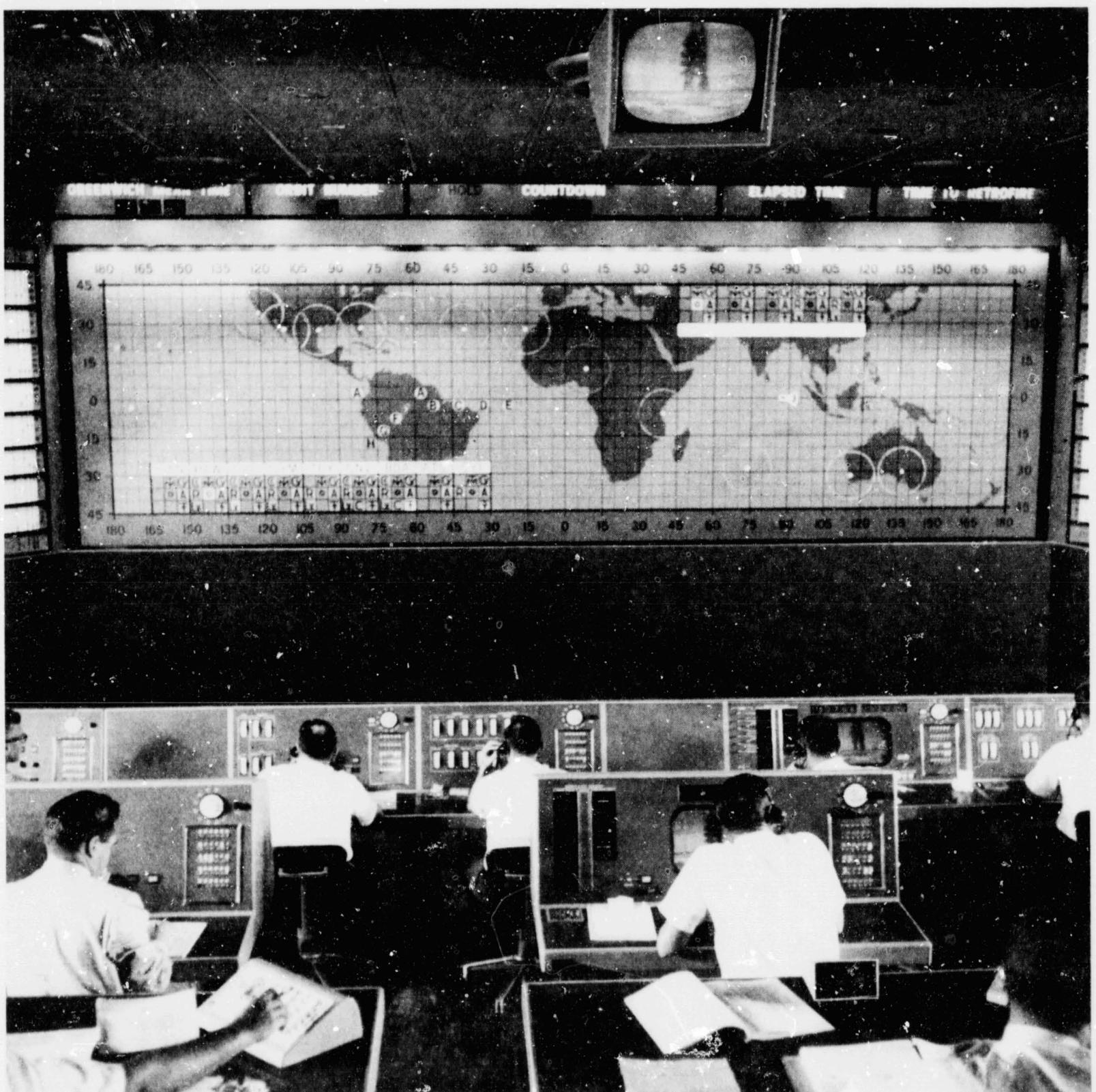
<i>Title</i>	<i>Page</i>	<i>Title</i>	<i>Page</i>
Mercury Control Center Showing Flight Controller Positions .....	iv	Construction of New Wing to Tel-3 Building (MCC) .....	55
NASA, Western Electric, and Team Member Representatives at Project Managers' Meeting .....	6	Indian Ocean Ship, <i>Coastal Sentry</i> .....	56
		Radio Equipment at Transradio Español, Grand Canary Island .....	57
		Digging Trench for Intersite Cable, Kano..	59

## LIST OF CHARTS

<i>Title</i>	<i>Page</i>
Over-all Project Schedule .....	3
Personnel Manning .....	5

## LIST OF TABLES

<i>Title</i>	<i>Page</i>
Major Systems Installed and Tested by W.E. Team .....	52
Site Completion Dates .....	54



This view of the Mercury Control Center shows the flight controller positions and the large world map.

# I

## PROJECT MANAGEMENT

On July 30, 1959, NASA awarded the Letter Contract for the implementation of the Project Mercury tracking and ground instrumentation systems to Western Electric Company. As prime contractor, W.E. was responsible for managing and directing the efforts of its Team Members—Bell Telephone Laboratories, Inc., Burns and Roe, The Bendix Corporation, and International Business Machines Corporation—to ensure the completion of the systems, as specified by NASA. This included responsibility for procurement and production, transportation, and installation and testing of equipment. In addition to the over-all management, W.E. was responsible for the design and implementation of ground communications required at the sites, the study of and leased arrangements for suitable inter and intrasite communications, and the training of maintenance and operational personnel.

Following award of the contract, construction of the 18 stations was begun without delay.

Construction was undertaken on a world-wide basis, with "building ready for installation" deadlines pacing the work. Site managers resident at each station and backed up by a technical staff in the field and Headquarters personnel in New York, directly supervised each phase of construction as well as all other field aspects of the project. Stations were constructed in Africa, Australia, on islands in the Atlantic and Pacific oceans, as well as in the United States. The round-the-world policy was to use local skills, materials, and labor wherever possible.

As construction neared completion at each location and scheduled shipments of Team Member equipment began, the tremendous logistics task of warehousing and then transporting tons of equipment by sea and air was begun to meet strict schedules. This was followed by the installation and field testing of equipment under the direction of the site managers.

Stations were equipped with wide-beam acquisition aids for locating the capsule as it comes within range of the station, and radars for track-

ing the capsule and telemetry equipment to receive signals and voice messages from the astronaut and transmit voice messages to him. At some sites, command transmitters will send signals as may be required to bring the capsule to earth in an emergency. An emergency voice system is also provided in each of these transmitters. Radar and telemetry information is displayed on station equipment to help keep flight control personnel informed. Information obtained at each station will be communicated to a focal point to be used to track the capsule and watch over the astronaut.

Also of prime importance is the complex general-purpose site communications systems provided to permit instant intrasite communications capability during all phases of the Mercury missions.

The focus for the global flow of data was established at Greenbelt, Md., in NASA's Goddard Space Flight Center (GSFC)—the communications hub of the entire system—where the capsule's path through space will be computed. Computer programs were prepared for the twin 7090 computers at GSFC. These machines, among the largest, fastest, and most versatile ever built will, by virtue of their special Mercury program, establish that the space capsule has gone into orbit properly, compute tracking data, and determine the proper retrofire and re-entry time.

At Cape Canaveral, Florida, where the astronaut will be launched into orbit, the Mercury Control Center (MCC) was established. This center will be the focal point to which all information on the orbital flight will be relayed from GSFC and from here all flight commands will be given or delegated.

The 18 tracking stations, GSFC, and MCC were tied together by a global communications network. Each remote station was given direct connection to GSFC. High-frequency radio was used where necessary to link the more remote stations with transocean telephone cables. Agreements were negotiated for leasing required cir-

cuits to complete the network needed to interconnect the stations. These negotiations involved coordinating efforts with communications agencies of Canada, Spain, Mexico, Australia, and Great Britain, as well as Bell System and other communications companies in the United States. At the same time, GSFC and MCC were linked by voice, high-speed data, and teletypewriter lines. Altogether, the Mercury system involved approximately 60,000 route miles of communications facilities.

At the tracking stations an intensive training program was carried out for the maintenance and operating personnel to be located at each site. As a forerunner to this training, maintenance and operating manuals were prepared covering all equipments provided for the project.

The result of these efforts is the tracking and ground instrumentation systems, incorporating a wide variety of features necessary for the success of the Mercury mission.

Early in 1960 the Demonstration Site at Wallops Island, Va., was established as a laboratory to demonstrate the performance of the major instrumentation systems and subsystems such as radars, acquisition aids, and telemetry and vehicle communications. This site, which is essentially a duplication of a typical Mercury site, was ready for equipment evaluation work on August 23, 1960. By mid-December demonstrations were completed to NASA's satisfaction at this site, having used both instrumented aircraft and launch vehicles such as Little Joe and Scout as dynamic targets.

Starting in July, 1960, with the MA-1 (Mercury Atlas) launch and continuing with the MR-1 (Mercury Redstone) launch attempts in November, 1960, Mercury telemetry, command communications, acquisition, and launch monitoring subsystem equipment at Cape Canaveral, Grand Bahama, and Grand Turk Islands functioned and provided varying degrees of useful data to NASA. These launches were terminated due to capsule or launch vehicle malfunctions which precluded a complete demonstration of the Mercury ground equipment's readiness and capability at these sites.

On January 31, NASA launched a Mercury capsule carrying a 37-pound chimpanzee 420 miles over the Atlantic from Cape Canaveral. All Mercury equipment at Cape Canaveral,

Grand Bahama Island and Grand Turk Island, performed satisfactorily during the launch and flight. In addition, the Atlantic Ship (docked at Mayport, Fla.) and the Bermuda station successfully tracked the capsule and obtained useful data for evaluation by NASA. On April 25, 1961, MA-3 was scheduled for launching, with the Mercury capsule to make a complete one-time orbit of the earth. While this launch failed because of a launch vehicle malfunction, all of those Mercury stations around the world required to participate were in a continuous state of readiness throughout the countdown and were prepared to support this NASA mission.

On May 5, 1961, an astronaut was successfully launched on a downrange flight from Cape Canaveral. During this mission, designated MR-3, all Mercury equipment at Cape Canaveral, Grand Bahama Island, Grand Turk Island and the Indian Ocean Ship, specially assigned to this mission, performed satisfactorily. This included the Mercury Control Center and associated telemetry, ground-to-air, and communications equipment. The Bermuda and Eglin sites also tracked the astronaut's flight.

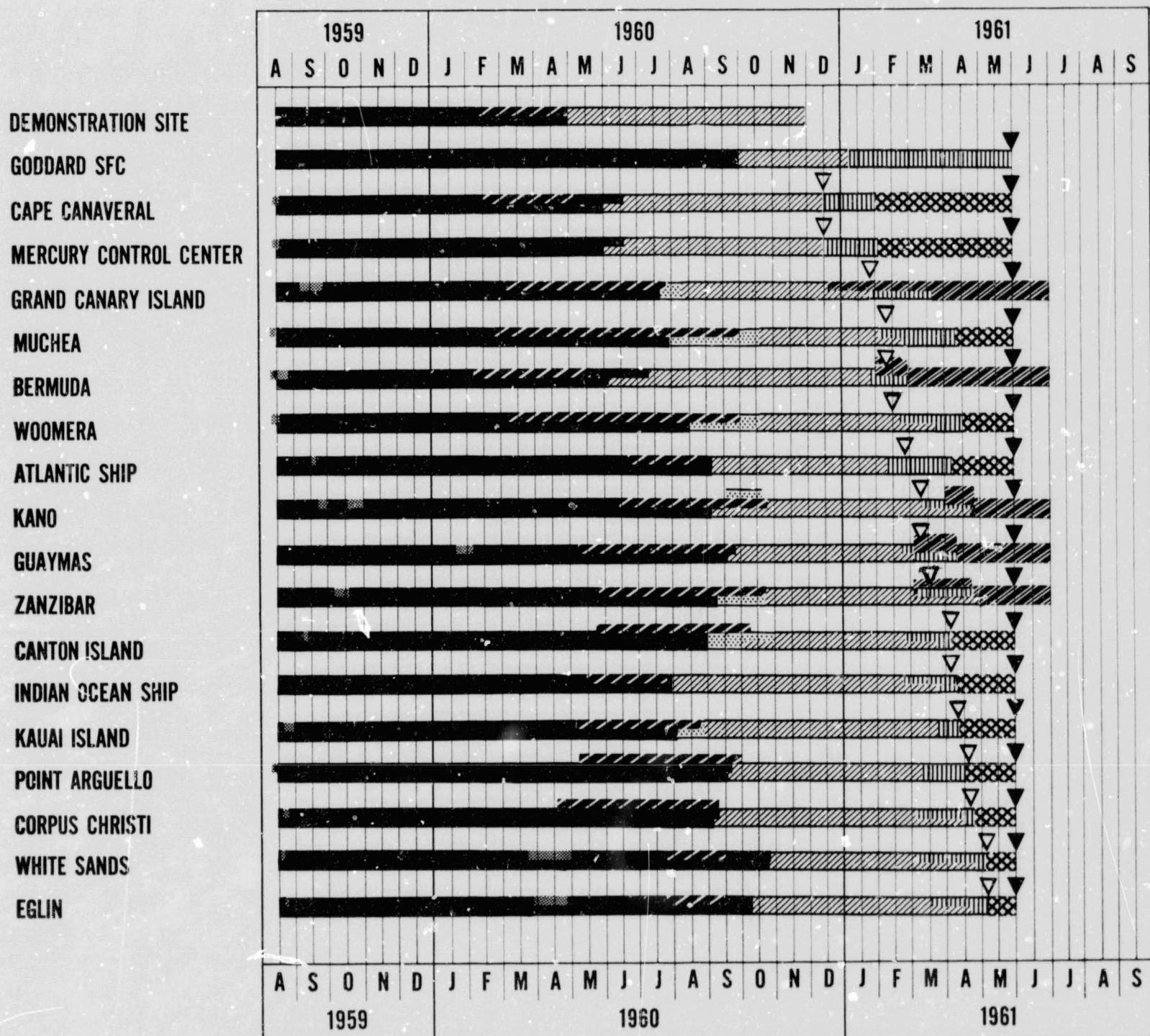
## SCHEDULING

NASA's authorization to proceed with implementation of Project Mercury included an agreed-upon requirement for complete project implementation by September 15, 1960. As implementation got under way, an over-all project schedule for each site was developed, establishing target dates for construction, transportation, installation, testing, training, and drills to support this date.

Utilizing this schedule, each Team Member developed, on a site by site basis and by major equipment categories, detailed schedules covering the design, engineering, construction, procurement, production, transportation, installation, and testing effort for which they were responsible, reflecting dates required to meet the over-all schedule. These schedules were then integrated into detailed master site schedules which were kept current, and all schedules were continuously checked with the Team Members for progress and identification of problem areas.

Associated with this activity was the establishment of the Team Member Scheduling Coordi-

## OVER-ALL PROJECT SCHEDULE



### LEGEND

	PROCUREMENT		INSTALLATION AND TEST
	SURVEYS		TECHNICAL MONITORING
	STATION DEVELOPMENT		WECOM & O
	OVERSEAS TRANSPORTATION		PROVISIONAL ACCEPTANCE DATE
	M & O TRAINING AND SITE TEAM DRILLS		NETWORK OPERATIONAL DATE

nation Committee, which met in the early phases of the project to establish uniform scheduling procedures. As implementation effort increased, this activity was supplemented by visits to Team Member plants where scheduling personnel participated in meetings to review local progress and problem areas. In addition, at each Project Managers' meeting, updated master site schedules, supported by information on progress and specific scheduling problems were distributed and discussed, and appropriate corrective action as required was agreed upon.

At the height of the project's implementation activity, more than 160 individual schedules were being reviewed and enforced.

During the course of the project, schedules were revised as necessary to reflect additional NASA requirements introduced into the program by CCN's and Mercury Change Orders, as well as the NASA schedule changes indicated below:

<i>Date of NASA Change</i>	<i>New NASA Project Operational Date</i>
September 14, 1959	November 15, 1960
October 9, 1959	January 1, 1961
May 2, 1960	January 25, 1961
April 1, 1961	June 1, 1961

To enforce the schedules and to be completely aware of potential schedule slippages, it was necessary that scheduling personnel be cognizant of the status of all phases of Team Member activity. To assist in this effort, in view of the magnitude of the task, the Open Item Report was conceived and published. The main intent of this report was to reflect the status of all open items, particularly in the design and engineering areas which, if not resolved expeditiously, would have jeopardized the meeting of scheduled deliveries of equipment. This report was revised weekly, and was distributed to all Team Members and NASA for review and action. It also included open items involving NASA.

Procurement representatives were established at some Team Member plants to assist them in expediting deliveries of components from their vendors to support project schedules when it became evident such action was necessary.

In the later stages of equipment deliveries to the sites and during the installation phase it

became apparent, in view of the remoteness of the sites, that miscellaneous material shortages due to late ordering resulting from engineering changes, damaging of material in transit, and defective parts might present a major problem. While this type of difficulty had been anticipated and routines had been established to care for it, extraordinary effort was required to ensure expedited delivery as, in many instances, installations were somewhat delayed by them.

The project has proceeded in accordance with the Over-all Project Schedule chart and as reflected in other sections.

#### PERSONNEL MANNING

As will be noted from the Personnel Manning chart, immediately following award of the Letter Contract, personnel manning got under way as required to implement the project. Western Electric personnel were drawn from various operating companies of the Bell System and other W.E. organizations to provide a management staff of highly qualified people. This force, as well as that of each Team Member, was rapidly increased to a total of more than 1000 people at the peak of the project. Personnel requirements ran ahead of the initial forecasts due to the various schedule extensions mentioned earlier, as well as introduction of many added tasks not previously contemplated. At the present time, personnel are being phased out of the project as basic tasks are completed.

The major tasks remaining, requiring personnel support through June 30, 1961, are the maintenance and operation responsibility at Bermuda, Grand Canary Island, Kano, Zanzibar, and Guaymas (Letter Contract 2); engineering assistance for the Mercury ground communications network (Letter Contract 3); the supply depot at Camp Kilmer, N.J. for logistics support to the five M&O sites (Letter Contract 4); the development and maintenance responsibility for the computing programs; and the maintenance of the launch subsystem equipment at Cape Canaveral and Goddard, including maintenance of the B simulator at the Mercury Control Center.

#### PROJECT MANAGERS' MEETINGS

To fully coordinate the activities of all Team Members during the project's implementation,

## PERSONNEL MANNING

	1959					1960										1961									
	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J		
<b>BENDIX</b>																									
DOMESTIC	FORECAST																								
	ON ROLL	88	103	124	149	159	173	204	310	509	484	502	469	419	338	249	233	230	223	218	223	170	99	59	
FOREIGN	FORECAST																								
	ON ROLL	1	2	2	5	1	2	1	4	10	23	42	57	72	97	136	172	175	174	158	140	136	131	124	
<b>BURNS AND ROE</b>																									
DOMESTIC	FORECAST																								
	ON ROLL	32	73	91	93	125	126	142	183	188	163	134	104	113	118	98	92	67	61	54	36	32	18	18	
FOREIGN	FORECAST																								
	ON ROLL	3	4	2	3	5	12	31	63	90	33	36	58	56	66	76	72	74	116	111	109	60	15	0	
<b>IBM</b>																									
DOMESTIC	FORECAST																								
	ON ROLL	17	21	21	29	29	36	62	71	72	72	72	76	75	77	86	91	90	107	107	128	121	108	112	
<b>BTL</b>																									
DOMESTIC	FORECAST																								
	ON ROLL																								
	11	9	11	14	16	15	19	20	19	20	21	21	18	16	14	12	12	12	12	12	12	12	12	12	
<b>WESTERN ELECTRIC</b>																									
DOMESTIC	FORECAST																								
	ON ROLL	42	75	93	104	110	130	142	157	175	179	185	223	254	257	259	242	228	225	209	205	176	152	111	
FOREIGN	FORECAST																								
	ON ROLL																								
	6	9	9	9	9	9	8	9	10	10	9	23	45	43	35	35	33	30	28	23					
<b>PROJECT TOTAL</b>																									
DOMESTIC	FORECAST																								
	ON ROLL	179	272	329	386	432	476	566	737	959	917	913	891	881	811	713	676	631	630	600	604	511	389	312	
FOREIGN	FORECAST																								
	ON ROLL	4	6	4	8	12	25	41	76	109	64	87	125	138	172	235	289	292	325	304	282	226	174	147	
TOTAL	FORECAST																								
	ON ROLL	183	278	333	394	444	501	607	813	1068	981	1000	1016	1019	983	948	965	923	955	904	886	737	563	459	
	A	S	O	N	D	J	F	M	A	M	J	J	J	A	S	O	N	D	J	F	M	A	M	J	
	1959					1960										1961									

FOREIGN: PERSONNEL ASSIGNED TO LOCATIONS OUTSIDE CONTINENTAL UNITED STATES.

DOMESTIC: PERSONNEL ASSIGNED TO LOCATIONS WITHIN CONTINENTAL UNITED STATES.

Project Managers' meetings were held every two weeks. These meetings, led by the W.E. Project Mercury Manager, were attended by Team Member Project Managers and key members of their staff, as well as by NASA representatives. The first meeting was held at W.E. offices in New York in August 1959. At these meetings, policy procedural questions were resolved, all major problems were reviewed as was the Project's progress, and working level Team Member committees were established as required to review and coordinate specific areas of project activity and make reports at subsequent meetings. The thirty-third and last of these meetings was held on May 24, 1961.

## CONTRACTING

On July 30, 1959, NASA awarded a letter contract to W.E. for Project Mercury. This task was to be implemented per NASA Specification S-45A, dated July 29, 1959, revised August 7, 1959, and superseded by revised Specification S-45B, issued October 30, 1960.

The cost estimate on the Letter Contract was submitted to NASA on November 10, 1960. A superseding definitive contract was executed on January 11, 1960.

More than 500 engineering changes to Project Mercury have been processed. Of this total, CCN's have been issued for approximately 160.



*NASA, Western Electric, and Team Member representatives discuss progress at one of the thirty-three Project Managers' meetings.*

About 60% of these CCN's have been definitized to date.

The following is a list of all the change orders (C/O) and supplemental agreements (S/A) to the basic contract received to date.

C/O No. 1—Provided additional funding.

C/O No. 2—Provided additional funding.

C/O No. 3—Provided additional funding.

S/A No. 4—Incorporated the Revised Spare Parts Provisioning Document, dated April 6, 1960, and provided no-charge use of certain Government facilities.

C/O No. 5—Provided additional funding.

S/A No. 6—Incorporated the Flight Risk Clause.

S/A No. 7—Definitized CCN No. 13, TTY Spare Parts Production List No. 1W, and increased the contract value accordingly.

S/A No. 8—Incorporated Addendum No. 2, revision to Specification S-45B.

S/A No. 9—Definitized CCN No. 1, Launch Subsystem, and increased the contract value accordingly.

C/O No. 10—Incorporated the March 31, 1960, cost overrun and provided additional funding.

C/O No. 11—Provided additional funding for CCN No. 1, Launch Subsystem.

S/A No. 12—Definitized CCN's 2, 3, 6, 9, 15, and 22.

S/A No. 13—Definitized CCN's 7, 10, 16, 21, 25, and 29.

C/O No. 14—Incorporated the July 31, 1960, cost overrun and provided additional funding.

S/A No. 15—Definitized CCN's 4, 5, 11, 18, 26, 32, 36, 42, 52, 34, 37, 38, 44, 45, 46, and 48.

S/A No. 16—Definitized CCN's 8, 19, 28, 30, 31, 33, 35, 39, 41, 43, 51, 53, 54, 57, 61, and 68.

S/A No. 17—Amended Specification S-45B to add spare parts provisioning procedures.

S/A No. 18—Revised the contract to include the no-charge use of additional Government facilities and special tooling.

S/A No. 19—Amended Specification S-45B and incorporated a revised Spare Parts Provisioning Document.

S/A No. 20—Definitized CCN's 20, 23, 24, 60, 67, 27, 70, 50, 64, and 62.

S/A No. 21—Incorporated the October 31, 1960, cost overrun and provided additional funding.

S/A No. 22—Definitized CCN's 68, 75, 85, 96, 72, and 99.

S/A No. 23—Incorporated provisions for handling foreign income tax for Mercury personnel.

S/A No. 24—Definitized CCN's 56, 65, 66, 69, 71, 73, 100, 74, 76, 77, 80, 81, 82, 87, 112, 92, 93, 38, 95, 98, 106, and the spare parts submission dated March 17, 1961.

S/A No. 25—Definitized five CCN's 89, 99, 103, 105, and 135.

S/A No. 26—Incorporated \$2,274,700 of the January 31, 1961, overrun into the contract.

S/A No. 27—Letter Contract No. 3, as negotiated, has been executed by W.E. and returned to NASA for final execution.

S/A No. 28—Letter Contract No. 2, as negotiated, has been executed by W.E. and returned to NASA for final execution.

S/A No. 29—Letter Contract No. 4, as negotiated, has been executed by W.E. and returned to NASA for final execution.

Five cost overrun proposals have been submitted to NASA, four of which have been incorporated in the contract. The fifth is under review by NASA.

The following letter contracts have been received from NASA:

No. 2—Services and materials to maintain and operate five sites, through June 30, 1961.

No. 3—Services, personnel, material, and facilities for engineering assistance for Mercury ground communications network, through June 30, 1961.

No. 4—Establish supply depot at Camp Kilmer, N.J., for logistic support for five sites, through June 30, 1961.

Cost estimate proposals totalling approximately \$4,500,000 for definitization of these letter contracts have been submitted to NASA and definitization has been accomplished. It is expected that additional Supplemental Agreements will be received, definitizing CCN's previously quoted. In addition, new CCN's are expected to cover recently approved changes.

#### SYSTEMS ENGINEERING GROUP (SEG)

This group was formed in October 1959 with representation from all Team Members to consider the over-all system from a functional point of view. This organization developed integration plans for each station and prepared functional block diagrams on a site-by-site basis. It also assisted in determining changes in system requirements after evaluating technical specifications, compatibility of equipment, costs, and effects on schedules.

In 1960, SEG established the basic precepts under which BTL prepared the technical acceptance requirements for checking out the Mercury equipment to meet operating needs. This was accomplished by Team Members submitting unit and subsystem test procedures to BTL for review. BTL, W.E., and Team Members established critical parameters for testing the subsystems and developed integrated subsystem tests to determine the satisfactory operation of the Mercury system. A basic approach to the Mercury testing program was established by developing an over-all policy for testing at the Demonstration Site.

The plan for preparing unit and subsystems tests was revised by work groups of representatives from NASA, Lincoln Laboratory, and the W.E. team. These groups were established at the

Demonstration Site and worked from manufacturers' specifications as well as actually making the tests on the equipment. The Team Members also drafted Mercury operational requirements for submission to range officials. It was also necessary to establish IBM and range interface requirements for the data systems being installed.

Special subsystems and unit tests were developed for range support of the Mercury Redstone mission. Test procedures that were prepared at the Demonstration Site were then reviewed and distributed. Issue 1 unit and subsystem test procedures were published and distributed. Subsequently, based on field experience as well as foreign review, Issue 2 procedures were prepared and distributed.

SEG assisted in the preparation of Demonstration Site operational tests series (DSOTS). In addition, draft copies of the Langley and Cape Canaveral simulation tests were prepared. Meetings were then held to review the Computation and Data Flow Integrated Subsystem Test (CADFIST) program and to review the participation at Grand Canary Island. A study report on the program to check out and verify operations of the radar digital data systems (MER-70) was reviewed and distributed at Langley Field. Test result data sheets were received from the various sites, and an analysis program was established. Phase II of the MER-70 program, the evaluation of the checkout of the approach, was conducted at Grand Canary Island and Bermuda, and analysis reports were forwarded to NASA. Brief systems tests were prepared to be used during the countdown procedures and were tried at Grand Canary Island. Necessary revisions were made to these tests as experience on missions became available.

Early in 1961 the voice acquisition telemetry simulation (VATS) was developed by Lincoln Laboratory. CADFIST use of the equipment began almost immediately at Grand Canary. Plans to provide radar azimuth elevation simulation (RAZEL) were also finalized during this period.

#### ENGINEERING COORDINATION

During the implementation of the project, W.E. engineering liaison was established among The Bendix Corporation, IBM, BTL, and NASA in processing technical proposals for electronic

equipment. This included the analysis of proposals to verify that they adequately covered system requirements. Comments on these analyses were compiled and forwarded to NASA, together with the proposals, for final technical approval. After submission to NASA the status of the proposals was monitored and appropriate Team Members were notified when NASA approval was received. In some instances, NASA approval was granted with the understanding that the proposals would be modified. When this occurred, follow-up action was taken to ensure that the Team Members complied with the NASA requirements. Major effort was also required for the preparation of site implementation plans. This required a review of system requirements, determination of availability of existing range equipment, and integration of the range and Mercury facilities. Mercury change orders were initiated and reviewed to authorize numerous engineering changes.

On-site system and unit testing was supervised until the latter part of 1960 when this function was taken over by the field test coordinators. The scheduling of the instrumented aircraft dynamic testing of the sites was also accomplished and testing on the aircraft was supervised.

Engineering support was provided for various sites by obtaining answers to Team Member technical problems and providing a central location to which the W.E. site personnel could refer questions.

The dynamic testing of the Mercury tracking and ground instrumentation system at each site was accomplished by an instrumented aircraft. In addition to conducting dynamic tests at the worldwide Mercury sites, considerable testing was done at the Wallops Island Demonstration Site.

## SITE MANAGEMENT

In implementing the site requirements of the project, site managers were selected and established at the stations to coordinate and oversee all Team Member and associated site activities. These activities included construction, installation, testing, supervision of the training administrators and warehousing and transportation representatives, the field implementation of schedules and changes, and maintenance of contacts with local agencies. Corollary effort involved the

supervision and direction of construction activities at the Headquarters level, together with proper site coordination. Engineering and design coordination was undertaken together with the evaluation of Team Member requirements for equipment space, power, air conditioning, etc., and assistance in the design and selection of pre-purchased construction material and equipment. As much equipment as possible was standardized to facilitate operating and maintenance instructions and procurement of spares.

A site managers' handbook was prepared, and many technical problems concerning real property, utility equipment, and site preparation were resolved. Construction change order procedures were established and required changes were co-ordinated with Team Members and site managers. In addition, intergovernment agreements were reviewed for their effect on personnel, access, procurement of materials, contracting, and site preparation, and specific directions were issued to affected sites as required.

Building utility design drawings and equipment specifications were prepared for NASA technical approval and their implementation was subsequently coordinated with Team Members.

Coordination was also undertaken in the procurement and expediting of utility materials to the sites. This involved working closely with warehousing and transportation personnel to establish realistic arrival dates for such material and other Team Member equipment. Procedures were established for spare parts at all sites and depots. An emergency requisitioning procedure was also established with the field to facilitate receipt of spare parts at the sites prior to the arrival of final M&O spares on the site. A spare parts status report is prepared monthly for NASA. Supplemental Agreement No. 19 was issued by NASA which amended Specification S-45B and incorporated a revised spare parts provisioning document to permit W.E. to procure required spare parts within an authorized dollar limitation without prior NASA technical approval.

The procedure for the operation of the NASA depot at Camp Kilmer was prepared to accommodate bulk ordering, separation for distribution to the sites and depots, stocking and handling of depot peculiar item spare parts, and coordination of shipment of spare parts to the sites and depots.

Over-all property and accountability procedures affecting Project Mercury were also established.

One of the major efforts was the preparation of provisional and final transfer procedures for real property and C&E equipment. Inventory documentation from Team Members was collected and distributed to the sites for final checking. Representatives of the W.E. team and NASA personnel in conjunction with personnel in the field, accomplished inventories and actual transfers of property at the 18 sites. Construction and C&E deficiency reports were then sent to NASA and followed to completion.

#### **FIELD TEST COORDINATION**

Beginning in late 1960, a weekly status report was issued indicating the status of installation and testing at each site. This report showed the current status of each subsystem, the site manager's forecast of expected completion dates, and a list of major problems delaying completion of installation and testing so that corrective action could be taken. All sites were forwarded necessary testing instructions. Test data was properly recorded at the stations and returned for analysis by the systems engineers. The assignment and movement of all Team Member site personnel was also monitored. The sites' personnel requirements were analyzed and decisions on assignments coordinated with Team Members. Assistance during the installation of intercom and teletype equipment was provided by the assignment of installation supervisors to the sites.

A schedule was issued periodically showing target dates for the completion of equipment installation and the various phases of testing and operations training for the sites. Assistance was given to NASA in the preparation of its Program

Management Plan by furnishing biweekly forecasts and dates for designated program milestones. Assistance was given to the site managers in clearing certain items appearing in the deficiency lists following provisional site acceptance. This assistance was limited to those items in the C&E equipment list which could not be resolved locally at the sites and required Headquarters assistance.

#### **PHOTOGRAPHIC DOCUMENTATION**

Approximately 1650 35mm color slides, documenting construction and equipment installation at all Mercury sites and Wallops Island and equipment at W.E. and Team Member plants were forwarded to NASA during the course of the project.

#### **MOTION PICTURE DOCUMENTATION**

Seven monthly motion picture reports and one final report, totalling 12,000 feet of film, documenting construction and equipment installation at all Mercury sites and Wallops Island, dynamic test aircraft, Team Member equipment, and warehousing and transportation efforts were forwarded to NASA during the course of the project.

#### **PUBLIC RELATIONS ACTIVITIES**

Approximately 100 press releases, prepared by the Bell System and Team Members and their contractors, were reviewed by W.E. and forwarded to NASA for approval.

Western Electric provided assistance to representatives of *National Geographic Magazine* and other periodicals for preparation of Project Mercury articles.

## II

# TEAM MEMBERS' REPORTS

### **WESTERN ELECTRIC COMPANY, INC.**

#### **LEASED COMMUNICATIONS**

During the course of the project, negotiations were conducted with foreign and domestic carriers for the leasing of ground communications. Within the United States, Canada, and Mexico nearly all types of standard voice and telegraph facilities are being used. This includes open wire, open wire carrier, voice frequency cable, microwave radio relay, and coaxial cable. In practically all instances, these circuits are being leased from the operating companies of the Bell System, independent telephone companies, and Teléfonos de México.

Between the mainland of the U.S. and Hawaii and from the North American Continent to the British Isles, circuits in the submarine cables are utilized. Beyond Hawaii and Great Britain and to the two ships, HF radio is being used. At least two independent HF radio links will serve Bermuda during Mercury missions. To back up the HF radio link established between Sydney and Hawaii, arrangements were made with the Overseas Telecommunications Commission of Australia and the Canadian Overseas Telecommunications Commission to lease their jointly owned telegraph cable between Sydney and Vancouver, B.C., during missions and other critical periods. In this way, reliability of telegraph communications is very high to Australia where two tracking stations will play a vital role in determining accurately the parameters of the capsule's orbit. Landline voice and teletypewriter circuits between Sydney and Muchea have been leased from the Australian Post Master General Department. Teletypewriter circuits in Australia operate at a speed of 66 wpm. Therefore, speed conversion equipment was required at overseas junction points.

The Australian terminal of the Perth to Indian Ocean Ship is provided by Overseas Telecom-

munications Commission of Australia to complete a two-channel radio teletypewriter system. Service between England and the Canary Islands is provided by an HF radio system jointly owned by the British Post Office and Transradio Española. The latter company also provides terminal equipment for an alternate path from the Atlantic Ship via the Canary Islands and London. The link between Kano and Zanzibar was provided by a completely new two-channel radio teletypewriter link procured and installed for NASA under the W.E. contract.

HF radio communications between Canton Island and Hawaii are provided over a link procured by W.E. and installed by FAA at both terminal locations. In Hawaii the Hawaiian Telephone Company has provided interisland communications facilities between Oahu and Kauai, as well as local trunk facilities on both islands. Service to Mexico is provided on existing open wire routes between Nogales on the Mexican-U.S. border and Guaymas. A Type-C carrier system will provide facilities for both the voice and telegraph channels. RCA Communications has joined Cable and Wireless, Ltd., in providing telegraph facilities over commercial facilities between New York and Bermuda while the Long Lines Department of AT&T, and Cable and Wireless, Ltd. are providing the joint radio telephone facilities serving Bermuda. To arrange leases for the facilities to be used in the Mercury communications network, it was necessary for W.E. to negotiate with 16 communications companies and agencies outside the continental United States.

#### **RADIO COMMUNICATIONS**

In July 1959 studies began directed toward preparing a communications plan for the project's international communications network. These included work on radio propagation, modulation

schemes, record searching of frequency users, and types of equipment and antennas. Details on communications facilities available at locations outside the United States were also acquired. In addition, inquiries concerning existing circuits, costs, and communications reliability were sent to appropriate common carrier companies. Various suppliers of equipment were invited to prepare specifications and cost information on communications equipment.

During the latter part of 1959, the basic communications proposal was completed and forwarded to NASA. Negotiations were then started for the manufacture of long-lead items of equipment. A draft of the Communications Plan was reviewed with NASA and operational requirements of the Space Task Group were developed. A number of circuit to foreign range stations were changed and over-all order wire facilities were increased. Advance drawings of the ocean ships were obtained from the Government and estimates were prepared to build model test antenna systems for these vessels.

Studies to determine radio transmission outage predictions on a number of alternate radio routes proposed by the Government were accomplished.

In 1960, various common carrier communications companies met with W.E. to prepare contracts for leasing circuits and to develop engineering plans. Engineering and funding arrangements to supplement existing FAA communications for NASA's use in Canton Island and Hawaii were reviewed and agreed to by the two agencies. The final radio equipment and systems proposal was approved by NASA, and studies of methods of interconnecting the Mercury sites were in progress.

Specifications for shipboard antennas, transmission lines, and shipboard fabrication work were prepared. An engineering survey was conducted aboard one of the ships to collect data on antenna placement, transmission line runs, and possible noise mitigation measures.

Representatives of NASA, NBS, Lincoln Laboratory, and W.E. developed a plan for using the North Atlantic Warning Service of NBS for Project Mercury needs. An interference and noise study group was organized at W.E., New York, to collect data on equipment characteristics and to analyze interference sources. A six-week schedule of prototype testing was conducted at

Camp Kilmer to determine equipment deficiencies, electrical characteristics of equipment, and operating procedures.

Most radio and associated communications equipment arrived in Jacksonville, Fla., in mid-1960, and installation was started on the ocean ships. Antenna farms were surveyed at Kano and Zanzibar and plans completed for a UHF radio system connecting the Zanzibar site with the local Central Telephone Office.

During the latter part of 1960, work on frequency selection for Mercury radios had proceeded to the point where applications could be submitted to NASA. W.E. recommended to NASA that additional receivers and patching facilities, along with appropriate filters, be provided at Grand Canary Island. The recommendation was made after an on-site investigation to determine the cause of unsatisfactory performance of the radio link between London and Las Palmas.

In 1961, effort was applied in clearing equipment troubles and developing fixes for communications equipment on the ship installation. Extra effort was needed at these installations because of severe vibration problems and closely spaced transmitting and receiving equipment. Unit, systems, and interference testing work was completed at the sites. A number of changes in frequency selections for radios used by common carriers were necessary. As the communications sites became operational, arrangements were made to transmit radio propagation information to GSFC via the Mercury network. These reports were used to correlate network propagation information with quality figures derived for the North Atlantic area and solar and geomagnetic activity. As the statistical relationships were better established, specific forecasts on propagation over various Project Mercury radio paths were made. Arrangements were also made to provide radio operators with updated maximum useable frequency (MUF) and frequency of optimum transmission (FOT) curves.

## VOICE COMMUNICATIONS

Work started on the voice communications system during 1959. Initially the work consisted of developing over-all requirements for a communications system, determining what equipment could be used and to what extent existing communications systems would be used at certain

sites of the world-wide network. Three separate communications networks were required for Mercury. An on-site network was necessary for intracomunications during Mercury missions to provide communication between personnel taking part in the mission operation. Another was the on-site support network, which was required for maintenance purposes and communication between other technicians. The last was a world-wide network linking the various sites with the GSFC switching center. It was determined that the support network could best be instrumented by using PBX switchboards. The world-wide network required 4-wire facilities which were obtained on a lease basis from existing communications networks and by installing private systems for NASA. This provided inputs around which types of equipment for the on-site Mercury mission intercom network were designed.

Preliminary communications requirements for all sites were established. Detailed plans were then formulated for the sites located outside the United States and an over-all communications plan was developed. 112A key equipment was chosen for the on-site Mercury network. However, the equipment required modifications to meet unique Mercury operating procedures.

NASA authorized the purchase of 112A key equipment for a number of sites, and a detailed plan for the intercommunication system was approved by NASA. A review of the on-site communications requirements brought about extensive modifications of the first plan. All design engineering, cross-connect information, and on-site cable requirements, except those required for late changes, were completed.

Mercury unit test procedures were developed for the intercom equipment and circuits. They were subsequently revised after testing at Bermuda and installation at Bermuda and aboard the Indian Ocean Ship.

The last major change in the intercom network was requested by NASA early in 1961. A number of these changes were completed for the MA-3 mission, and involved most of the sites.

## TELETYPEWRITER COMMUNICATIONS

Engineering of the various types of teletypewriter sets and special circuit arrangements to be provided was accomplished. This included preparation of block diagrams showing the intended operation of the system as well as line and equip-

ment terminating sketches to ensure a satisfactory means for restoring service in the event of trouble.

This work required coordination and consultation with the other Team Members and with many commercial communications carriers and outside equipment manufacturers, particularly those concerned with special telegraph repeaters and testing apparatus. The following paragraphs outline the activities associated with the handling of general engineering matters involving the teletypewriter network and the high-speed data network as well as the related instructions necessary for testing and maintaining the system.

Many engineering schematic drawings for systems and arrangements were developed and prepared. Requirements were also developed and arrangements completed for: provision of service over the Mercury network to facilitate the handling of traffic for logistic and administrative purposes; circuits to handle recovery traffic over the Mercury network; a new radio interference suppression unit to eliminate interference to adjacent radio receivers from No. 28-type teletypewriter sets; message formats to be used in handling traffic over the Mercury network as well as studies of the traffic load and distribution; and an interconnection arrangement between the GSFC-London submarine cable circuit and two points in the British Isles. Requirements were developed and arrangements were made for the provision of the many features and improvements at GSFC.

A proposal was submitted to NASA for providing circuit assurance with an automatic answer-back arrangement on the teletypewriter network. Engineering changes were completed reflecting the changes required to move certain switching equipment from Woomera to a location at or near Adelaide, where the equipment will be reinstalled with modifications in premises mutually agreeable to NASA and the commercial communications carrier. This arrangement is being developed to provide a common location in Australia for the termination of all NASA facilities, thereby permitting sharing of facilities among the various NASA projects.

Engineering site readiness evaluations were made and instructions were prepared and transmitted to certain site managers dealing with long-term reliability tests on the teletypewriter circuits assigned to HF radio facilities.

Tests were made between GSFC and Woomera, using the Vancouver-Sydney cable, to obtain a clear understanding of the modifications made by the Canadian Overseas Telecommunications Commission to effect satisfactory conversions between the start-stop and the TTY on cable (TOC) teletypewriter systems without manual relaying. The cable was subsequently used successfully during preparations for the MA-3 mission. Requirements were developed and arrangements were made to provide a full-period talk order wire connecting GSFC No. 1 Office and RCA Communications in New York with loudspeakers at all locations. This circuit is expected to be of considerable value in sectionalizing and clearing trouble conditions encountered in the day-to-day operation of the network.

The four full-duplex, high-speed (1000 bits per second) data transmission circuits between GSFC and MCC were put in operation in mid-1960. It was recognized that there was a need for testing and in-service monitoring of these circuits, and that every effort should be made to maintain the service as specified and provided. Western Electric and BTL recommended that the digital subset be used in conjunction with the Milgo units as terminal equipment. As a result of numerous meetings between W.E., NASA, BTL, AT&T Long Lines, IBM, Milgo Corporation, and Lincoln Laboratory, a trouble reporting procedure was put into use by AT&T and an out-of-service test procedure was provided by BTL. A demonstration was then performed to compare Milgo and digital subset performance under varying level and noise conditions. Work continues toward providing the best possible performance and highest degree of reliability obtainable. It is expected that NASA will decide in June 1961 whether to use the digital subsets as an integral part of the launch subsystem.

Instructions were prepared dealing with the initial acceptance of the teletypewriter network as well as its over-all operation and maintenance. A general review of all existing operation instructions was made to determine their adequacy and, as a result, a proposal was made which recommended certain changes to facilitate their use and to remove duplicate and erroneous information.

## EQUIPMENT ENGINEERING

Equipment engineering work followed completion of each phase of engineering effort. In many instances, due to the short schedules involved, it was undertaken on a concurrent basis. The task involved ordering of equipment and the assignment of it within the Mercury site buildings in the most effective manner. Decisions as to the most expeditious manner to be employed in installation, whether to assemble on site, or to preassemble equipment at the factory, were also necessary. In addition, liaison was established with The Bendix Corporation, IBM, and BTL when interface problems developed. Necessary interconnection drawings were prepared.

Job specifications were issued covering manufacturing instructions for the fabrication of the equipment as well as installation instructions enabling site personnel to correctly assemble equipment. Appendixes to the original specifications were issued due to many changes in design. Station drawings were prepared to support the specifications and appendixes.

During the course of installation work, visits were made to the various sites to assist with installation problems.

The basic equipment engineering task has now been completed. Effort remaining involves the completion of a number of modifications suggested by NASA, provisioning of technical advice to the field sites during the turnover, and assistance in the correction of all drawing records to show the as-built condition at all sites.

## TRAINING

The training effort for Project Mercury was divided into five main categories: indoctrination, individual (on-the-job) training, system team training, site team drills, and network drills.

### Indoctrination

This phase of the training consisted of 18 hours of classroom instruction by the training directors at each Mercury station. The subject matter included elementary material on space flight, earth orbits, and a general introduction to Project Mercury. The course is described in *Indoctrination Course, Operations and Training*,

which was distributed to the training directors at each site. The manual contains outlines for nine two-hour lectures plus a list of suggested training aids.

### Individual (On-The-Job) Training

The training directors at the site supervised the instruction efforts of the various system team leaders who trained their individual members to compensate for any discrepancies between desired and actual skills. The amount of this type of training varied, of course, with the number and extent of these discrepancies and was continued until the training director, the M&O supervisor, and the NASA on-site representative were satisfied that each man had the necessary qualifications to carry out his work assignment. Training material for this phase consisted of the applicable equipment and system manuals.

### System Team Training

During this phase, each M&O team at the site was taught procedures for setting up, testing, calibrating, and operating the particular equipment to which the team had been assigned. The training, to be conducted by the team leaders under the supervision of the training director, included both lectures and actual experience with the equipment.

The content of this training is described in some detail in MT-101, *Instructor Manuals*. The manuals contain lesson outlines and tests to be administered by the team leaders to evaluate the effectiveness of the training. All necessary training materials are contained in the equipment and system manuals, procedures manuals, and drawings. Lists of specific references to these documents are incorporated in the lesson plans in MT-101.

### Site Team Drills

During this phase, at least ten simulated missions were conducted by the site under the supervision of the training director. The first two exercises did not involve all teams, but only those which interacted closely during a mission (e.g., acquisition, radar and data processing, and teletype; acquisition and telemetry). Debriefing and discussion sessions were held after each mission.

The exact nature of these exercises was left to the discretion of the local training director, but

MT-101 described methods for simulating various functions. Also included in this manual are scripts for a normal mission from T-5 hours to re-entry after three orbits. Each site was provided with telemetry tapes for normal orbital missions. Teletype tapes for incoming messages are to be prepared locally from the formats contained in MO-101, *Operations Procedures Manual*. The MO-101 manual also contained a countdown and specific operations procedures for each M&O team. Although all material supplied referred to normal missions, it is anticipated that site training directors may deliberately introduce abnormalities during some of these exercises.

### Network Drills

To ensure that the procedures used at each site are compatible with the requirements of the Mercury mission, simultaneous exercises were held involving all the sites.

To a large extent, network drills were identical to site drills. A test director distributed a network countdown to all sites and related the countdown document to GMT by a teletype message to the sites. Other than this synchronization procedure, the major difference between network exercises and site drills was that communications actually flowed between sites so that there was no need to simulate incoming messages.

During two weeks of the network drills, observers were stationed at key points to record the times at which various events occurred. The results of their observations were summarized in a formal report to NASA evaluating the ability of the network to support the mission.

### PUBLICATIONS

The composition of the Project Mercury publications program was influenced by several factors:

1. The time involved in procuring, publishing, and distributing Project Mercury manuals was limited by the early scheduled site operational dates.
2. Much of the equipment to be used at the sites was off-the-shelf items for which equipment manuals were already available, though not necessarily reflecting the modified form in which the equipment was to be furnished.

3. System manuals would be required to specify the manner in which various equipments comprising a system, such as telemetering, were interconnected.
4. Training manuals were required for training the operating and maintenance personnel for each system provided at the sites.
5. Site locations were dispersed at strategic locations around the globe.
6. Station construction personnel and, later, station operating and maintenance personnel would require information concerning the site to which they would be assigned and also the instrumentation they would expect to find at the site location.

During late 1959 and early 1960, it was decided that each Team Member would be responsible for furnishing equipment manuals for each equipment the Team Member was providing. Further, each Team Member was assigned the responsibility of preparing a system manual for each of its own systems. The W.E. document, *Project Mercury Publications Program*, outlined the minimum requirements for equipment and system manuals. This document specified that off-the-shelf equipment manuals could be used if they met the minimum content for equipment manuals and further provided that any modifications would be reflected in the equipment manual of the associated system manual.

For each equipment and system a distribution procedure was established to furnish copies for installation, training, and copies for the site file. Negotiations with NASA established the "additional number of negotiated copies" of manuals to be furnished to NASA as provided in S-45B.

As manuals became available for distribution, the first *Project Mercury Publications Distribution List* was published and given wide distribution. These lists specified for each site, each Team Member and NASA, the quantities of manuals which would be furnished each location. The final issue of this publication distribution list will be published in June 1961.

To keep NASA, the Team Members, and the sites informed concerning the status of the overall publications program, a status report, *Project Mercury Publication Summary*, was issued showing the scheduled shipping dates for each manual. A final status report will be issued in June

1961. It is anticipated at this time that all final issues of manuals will have been published and distributed by July 31, 1961.

## WAREHOUSING AND TRANSPORTATION

Arrangements were made to utilize existing warehouse facilities at Camp Kilmer and Seattle and, in mid-1960, it was decided to establish an additional staging area at Nogales, Arizona, to process and forward material to Guaymas.

### Warehousing

#### *Kilmer Warehouse*

A total of 406 short tons of equipment has been shipped from the Kilmer warehouse.

#### *Seattle Warehouse*

Approximately 263 short tons have been shipped from the Seattle warehouse.

#### *Nogales Warehouse*

The contract for use of the warehouse facilities at Nogales was terminated as of December 31, 1960. A total of 91 short tons of material was processed at the Nogales warehouse for Guaymas.

### Transportation

#### *Foreign Sites*

Field representatives were stationed at Bermuda, Grand Canary, Canton Island, Guaymas, Hawaii, Nigeria, Muchea, Woomera, Sydney, and Zanzibar. They were responsible for the receipt and turnover of installation material and for binning spare parts. These representatives also handled on-site and local transportation of personnel and material.

While NASA secured free permits to the foreign sites through appropriate diplomatic negotiations, it was necessary to secure a project export license from the U.S. Department of Commerce to ship W.E. and Team Member equipment to the foreign sites without payment of export duty. Approximately 1,074 short tons of cargo have been shipped to sites outside the continental United States.

The concept of packing preassembled units to the greatest possible extent resulted in a large number of oversized shipping containers. Ship

and airline schedules had to be reviewed constantly, and close cooperation with the staging area warehouses was required to program the movement of cargo to meet the required dates at the sites. It was necessary, in some instances, to divert shipments directly to the piers and in others to have the ocean carrier reschedule ports of call. In the case of Canton Island, which was a one-trip movement via ship, all available equipment was expedited to the Oakland Terminal. To obtain the maximum cargo possible, some supplies originally destined for other sites were diverted to the POE and subsequently replaced. A Western Electric representative was sent to Oakland to supervise the arrival and loading of the cargo.

After the start of installation at the sites, requirements for shipment of various miscellaneous material developed. Arrangements for movement of this material via the most expeditious method were closely coordinated by the W.E. Headquarters group with the staging areas, Team Members, and sites.

### Domestic Sites

Field representatives, stationed at eight domestic sites, were responsible for the receipt and turnover of all material and for binning spare parts. These representatives also handled on-site and local transportation of personnel and material. Approximately 439 short tons of equipment have been received at domestic sites.

### PERSONNEL

One field representative was assigned to each of the nine foreign sites and Sydney, Australia, and to eight of the domestic installations.

The field representatives at some of the overseas sites, notably Grand Canary Island, Kano, and Zanzibar, encountered less than optimum conditions in the performance of their duties. Unloading equipment was unknown at some locations; all operations were performed manually by local labor.

## BELL TELEPHONE LABORATORIES, INC.

Bell Telephone Laboratories has the responsibility for systems analysis, operations plans and operational tests, and for design of the command and control displays. Under BTL direction, equipment was designed and provided for the operations rooms in the Mercury Control Center and at Bermuda. A simulation system was also provided at Cape Canaveral to exercise the flight controllers and astronauts in the complex procedures required for an actual manned space flight.

The major features of the Mercury system were determined by prior actions and decisions on the part of NASA and were set down as a starting point by Specification S-45B, which established the numbers and types of radars and computers, the number and locations of sites, and certain basic policies with regard to objectives. To provide the information needed for understanding the intended workings of the system, and for defining lines of responsibility for engineering action, the Systems Analysis Group

was formed and received cooperation and assistance from all participants in the project, including Lincoln Laboratory and NASA, as well as the W.E. industrial team. The report from this group, issued in January 1960, was used as a guide during the remainder of the project.

Recognizing that the complex of equipment and operators distributed in a world-wide network would require closely coordinated operation, studies of the timing and sequences of events were initiated. Detailed operations plans for Cape Canaveral, Bermuda, Grand Canary, Muchea, and Goddard were provided to W.E. for incorporation in its operator procedure manuals. These operations plans were tested and further developed at Wallops Island by methods which had been devised for simulation of the passage of a capsule over a range site.

The Wallops Island tests in September and November 1960 were the first in a series of inclusive operational tests and examinations of a critical nature, designed and conducted in the

interest of providing guidance to W.E. by determining programs for corrective action. Assistance was received from NASA, Lincoln Laboratory, and W.E. personnel in this task. In February 1961, a critical survey of the Cape Canaveral, Atlantic Ship, GSFC, Bermuda, and Grand Canary sites was made (and reported) to evaluate their readiness for the MA-3 mission on the basis of the completeness and perfection of maintenance of the equipment and on the skill and training of the operators in following the procedures prescribed in the operations plans. In March 1961, the first network operational tests (MA-3 sites only) were planned, observed, evaluated, and reported. Each successive test has proven valuable by bringing out some items of weakness requiring corrective action. BTL activity in critically observing operations for evaluation continued throughout the MA-3 countdown and firing (April 10-25, 1961). Plans are being made to continue this activity by conducting and observing a simulated operation involving all sites on the network as an over-all Mercury ground range demonstration.

## CONTROL CENTERS

The Operations Room at Cape Canaveral is the focal point for all information in the system during all phases of the operation and is the point from which all commands will be issued or delegated. The secondary control center at Bermuda serves the purpose of confirming the validity of the insertion into orbit during the launch phase; on subsequent orbital passes it serves as a tracking site. After several conferences with WE and NASA, BTL prepared a proposal in September 1959 incorporating the composite of requirements for the control centers, as developed to that date; BTL selected Stromberg-Carlson to construct and install the required displays. (See Cape Canaveral and Bermuda in Part III for further information concerning implementation of the control centers).

## SIMULATOR

A major item assigned to BTL by W.E. was that of development of the simulation system that is now installed at Cape Canaveral and has been under continuous use since November 1960.

The simulation system is expected to provide such thorough exercise for flight controllers and astronauts that their familiarity with the complex procedures required will be letter-perfect when manned flight occurs. This simulator is designed to activate the Goddard computers as though a real launch were taking place and this, in turn, activates all of the computer-operated displays in the Operations Room and all of the computer outputs to remote sites, thus bringing in the entire network. All other displays in the Operations Room are also activated; for instance, the telemetry displays can be operated either from planned tape recordings or from an instructor's controls. Decisions of the flight controllers regarding missile flight events are realistically followed by appropriate indications from the computer; in other words, this is a closed-loop simulator in which human actions produce realistic results. An astronaut seated in the McDonnell Aircraft Corporation's Capsule Procedures Trainer can be coupled into the simulator system for communication and procedural training.

MS-120, *Simulation System—Cape Canaveral*, was delivered to the site in May. During the same month, NASA provisionally accepted the simulator. (See Cape Canaveral in Part III for further information concerning the simulator).

## TEST SPECIFICATIONS

Late in April 1960, BTL was asked to participate in the preparation of test specifications for the Mercury equipment. This specific assignment was to ascertain that the specifications to be used to test the site equipments were adequate to verify technical performance of nine noncomputer related subsystems. The program was seen to involve three levels of testing: the unit or component tests; the subsystem tests, which checked the performance of an aggregation of equipment designed to perform a systems function; and tests which involved the interconnection of several subsystems. A major responsibility for specifications for the latter two levels of testing was assigned to BTL.

For the expanded program, BTL prepared several preliminary subsystem and integrated subsystem test specifications and participated in a number of the initial subsystem tests conducted at Wallops Island. Also, BTL was active in all



of the working groups which were commissioned to formulate the site unit and subsystem test specifications. In most cases, BTL was instrumental in finally preparing the standardized specification for issue by W.E. The limits specified in the initial specifications were based on tests performed at Wallops Island by experienced personnel or were based on analyses of the equipment involved when such test information was unavailable. Considerable time was required at Wallops Island assisting in the test program to establish these limits and in preparing specifications. Assistance was obtained from the Sandia Corporation, particularly in the area of telemetry, to accelerate this work.

A total of 25 test specifications resulted from this program. Other specifications prepared with BTL assistance, or reviewed by BTL, included the aircraft flyover demonstration test, the integrated interference test, and the initial ground communication network tests. Several of the launch subsystem test specifications were reviewed as well.

The W.E. Systems Engineering Group issued the test specifications and collected the field test data; BTL aided in a review of the initial returns of this data. As a result of the review, changes to the specifications were initiated, generally in consultation with the appropriate Team Member. Most of the changes were of a procedural nature; limits were revised in a few cases also.

A review of later data from several sites indicated that, with few exceptions, the site equipment was meeting the requirements of the specifications, and the technical performance of the equipment was considered satisfactory.

## COMMUNICATIONS

Participation in communication system design and testing, although entirely in the nature of technical consulting on specific items, was of sufficient total magnitude to be reported here as a major item of BTL support to W.E.

### HF Radio

Bell Telephone Laboratories participated with the Bureau of Standards and W.E. to establish a program whereby the Bureau would compute data from which the performance of a considerable number of possible HF radio circuits could

be estimated. These data were used in determining the ground communications plan. Similar liaison was conducted in establishing a plan for prediction, by the Bureau, of path performance on an hour-by-hour, day-by-day, and month-by-month basis to assist NASA in avoiding launches at times when it would be unlikely that adequate ground communications could be achieved.

Also, BTL participated with W.E. in: (1) investigations of the preliminary designs of antennas for the ships, (2) studies to determine whether back-scatter sounding equipment should be used to determine the best frequency to use at any one time on HF radio circuits, and (3) considerations of the desirability of establishing ionospheric scatter radio circuits from the United States to Bermuda.

### Interference

Bell Telephone Laboratories participated with W.E. in studies of potential interference situations. A program was devised for an IBM 704 computer which permitted calculation of distortion products caused by two or more transmitters. The program now available is capable of computing all modulation products up to the tenth order and prints out any interfering products with certain specified proximities to receiving frequencies of interest. Detailed studies of potential influence at Bermuda were made. The interference test MIT-131 and the interference testing program for the Indian Ocean Ship, as well as 12 other reports, were the result of the work of the Interference Committee.

### Propagation

Studies and reporting on the actual operability of the teletypewriter lines involving radio links is a continuing item; some 20 reports have been issued to date.

### Transmission

Consultation services were provided in connection with several transmission problems, including transmission of telemetry signals over leased telephone circuits, transmission of timing and data signals over local cable circuits, and transmission of high-speed data signals over leased circuits between Cape Canaveral and GSFC.

In connection with telemetry transmission, W.E. and Bendix were advised of pertinent char-

acteristics of telephone circuits that would affect performance. The requirement for telemetry transmission over telephone circuits was dropped early in the program and no further work has been done along this line.

The greatest amount of transmission activity by far has been in the high-speed data transmission area. Noise, interference, and pulse distortion questions associated with the transmission of timing and data signals over local cable circuits were analyzed. It was concluded that noise and interference problems would probably not be troublesome; problems associated with circuit arrangements to minimize pulse distortion effects were defined to the point where W.E. could hand over circuit design requirements for terminal equipment to the appropriate agencies.

Initial studies led to the conclusion that it would be feasible to transmit data from Cape Canaveral to Goddard and back in order to use computers at Goddard for trajectory computations during the launch phase. Arrangements employing several circuits in each direction were recommended to ensure reliable operation. Requirements for transmission parameters such as attenuation characteristic and delay distortion were specified as an aid in arranging with AT&T for suitable leased circuits. Laboratory tests of Milgo data transmission terminal equipments revealed some undesirable performance characteristics of the Milgo equipment that led to a recommendation that Bell System digital subsets be used in place of the modulators and demodulators of the Milgo equipment. The modifications needed in both the Milgo terminals and the Bell System digital subsets to permit interconnection were determined and were recommended.

A simple technique for testing the performance of high-speed data circuits and associated terminals was described. Several items of special test equipment were constructed so that tests could be conducted on the circuits between Cape Canaveral and Goddard. An initial trial test of the technique mentioned above was conducted. Results of subsequent tests conducted by others were analyzed.

#### World-Wide Teletypewriter and Voice Networks

Extensive studies were also made by BTL on the world-wide communication facilities to gain assurance that the required information handling

capability existed at all times during a mission. These studies were constantly updated as operations plans were conceived and as the network structure developed. Transmission by both voice and teletypewriter were included in these analyses.

Since the teletypewriter system is considered the primary communication means, the analysis effort was principally addressed to these facilities.

The degree to which the traffic loadings could be defined was far more exact for the teletypewriter system than for the voice system and, therefore, the teletypewriter analysis was more rigorous. The results of these studies have shown where and when contention for circuit usage will occur and the extent of the delays encountered. Recommendations have been made to improve the traffic pattern and reduce the delays.

The hub of these communication networks is at GSFC. Switching equipment for both voice and teletypewriter networks is located at this point. Technical support in many areas to assist in the choices of appropriate switching facilities and equipment was provided by BTL. For the teletypewriter system, a specially engineered system with priority features has been installed and for the voice system a 4-wire switching arrangement with conference capability has been provided. These facilities have demonstrated their effectiveness in the operations tests and exercises preceding the MA-3 mission.

#### Intercom Facilities

The specialized requirements for intercommunication at sites and at Cape Canaveral were initially quite simple, but as the project progressed these facilities had to be expanded extensively. 112A key equipment, such as used in the call directors, was recommended by BTL as the most flexible to accommodate the changing needs. Also, BTL was consulted in many aspects of the intercom application, among which were problems of 4-wire operation, talking and monitoring arrangements, signalling, conferencing, and the interface with the intercom system at Cape Canaveral. These facilities have given satisfactory performance in all operational exercises and tests.

#### GENERAL TECHNICAL CONSULTING

In all technical matters on the project BTL served as consultant to W.E. A principal item

under this heading was consulting in all phases of communications; these activities were reported above.

Assistance was rendered to W.E. from time to time as requested on the problems of the acquisition aid, the radars, certain power supplies, and the shipboard vibration situation. Through the services of Sandia Corporation, considerable guidance was provided with regard to the planning, testing, and operation of the telemetry systems.

## COMPUTING AND PROGRAMMING

Throughout the project, BTL has monitored the computing and programming developments, acting as advisor to W.E. on matters pertaining to orbital mechanics, indicating the effects of certain orbital constraints and computer restraints

on the Mercury system, and generating recommendations to W.E. regarding items requiring action. The work comprised studies of data processing, computer programming, geophysical effects on the orbit, and effects of radar error on the computation.

By monitoring the IBM programming activities, BTL served as technical liaison between W.E. and IBM on problems and questions arising over the programs. An intensive study of the programs was made, the mathematical processes were reviewed, and special attention was given to numerical integration, differential correction, and data rejection methods. The logical structure of the program was investigated, with the monitor program getting special attention and incidentally being found to be well suited to its task of adapting the 7090 computer to a real-time environment.

## THE BENDIX CORPORATION

The Bendix Corporation was responsible for design of systems and fabrication of the telemetry instrumentation and site display equipment. In addition, Bendix handled systems design and fabrication of radar (except those furnished by the Government) and capsule communications equipment. Bendix was also responsible for equipment instruction at the sites.

### BENDIX RADIO

#### Contract Status

Early in August 1959, The Bendix Corporation received from W.E. a letter contract in anticipation of a CPFF contract for furnishing equipment and services for a tracking and ground instrumentation system for Project Mercury. On March 25, 1960, a CPFF contract, MYX-70003, was approved by the administrative contracting officer and formally placed with Bendix.

#### Systems and Other Engineering

##### S-Band Radar

After exhaustive investigation of available radars, purchase orders for six Verlort radars

were placed with Reeves Instrument Corporation. These radars are basically the same as those provided for the Discoverer program; however, some modification was required to enable the Verlort to perform acceptably in the Mercury system. Later a decision was made to use a seventh Government-furnished Verlort at Point Arguello. Modifications were necessary to provide acquisition and data handling features similar to those provided on the procured Mercury Verlorts.

After installation of the Verlort at Bermuda, jamming of the local surveillance and approach radar was experienced from the Verlort. To eliminate this interference, a modification kit was installed in the CPN-18, and the Verlort was provided with a sector blanking modification.

Reports from the digital data processing personnel on Mercury indicated that a severe mismatch existed between the Verlort digital output equipment and the digital-to-teletype converters. Transistorized buffers were built to overcome this problem.

Reports of tracking analysis indicated that two Verlort sites were experiencing tracking errors as a result of wind buffeting against the antenna. A study was initiated to ascertain if the Verlort could be adequately strengthened through minor

modification, or if it were necessary to install a radome to prevent this problem. A data package was submitted to NASA suggesting the procurement of a radome.

#### *S-Band Radar Modification*

A proposal was made to install a Verlort at Eglin, but the decision was made to modify an existing AN/MPQ-31. This modification was a major one in that it was necessary to increase the range to 2500 nautical miles and also to increase the range tracking rates to meet Mercury specifications.

#### *C-Band Radar*

The initial requirement for modifying seven AN/FPS-16 C-band radars to increase range and acquisition capabilities, was suspended after three months of discussion, analysis, and preliminary engineering with RCA. The original procuring agency requested that all contracting work with RCA on the FPS-16 be handled through its office, ending Bendix responsibility on this portion of the equipment.

One of the modifications to the FPS-16 required that Bendix Radio provide an intercommunications status indicator and time clock panel to be mounted on the IRACQ console. The clock was connected directly to the time standard system to provide accurate time to the FPS-16 operator.

#### *Radar Range Simulator*

A need for range simulators to be provided for all Mercury tracking radars was recognized, and a contract was let with Remanco Inc. to provide seven units for the FPS-16. These units were off-the-shelf simulators designed under a prior contract for the FPS-16, but modified somewhat to provide an orbital simulation mode for Mercury. The simulators for S-band radars were more demanding since they were required to simulate a moving target out to a range of 1000 miles. Two contracts were let: one with Reeves for five mechanical analog types, and one with Remanco for two electronic analog types. This procedure was taken since a much faster delivery had been promised on the electronic analog type.

#### *Data Switch Unit*

Since Project Mercury radars in many cases had to be shared with existing missile range facilities, it was necessary to provide switching facilities at these sites to preclude equipment mismatches, loading, etc. In this manner, the radar could be switched between existing equipment and the Mercury data processing equipment. This same requirement necessitated the provision of switching facilities on other data processing equipment at two of these sites.

#### *Data Processing*

At the beginning of the project, a study of system requirements for plotboards, polar-to-cartesian coordinate converters, data transmitters, and data receivers was initiated. As the tracking system evolved, this study was extended to cover synchro transmission methods, synchro speed converters, and cartesian-to-polar coordinate converters.

As system requirements were ascertained, detailed equipment purchase specifications were prepared and sent to prospective vendors. After evaluation of proposals, vendors were chosen, and data packages were submitted for approval. After placement of orders, vendor liaison was performed, when required.

Bendix personnel assisted in preparing preliminary test procedures for data processing equipment, then verified these procedures by actually performing equipment tests at Cape Canaveral. From the results of these tests, final procedures were prepared.

Engineering assistance was provided during the installation and test of data processing equipment at all sites. Several incompatibilities were found between the equipment and the radars, and modification kits were provided as necessary. Additional site backup in the form of technical assistance in procuring replacement parts was also provided.

#### *Timing*

A study of timing system requirements was started early in the project. It was soon decided to use the basic Minitrack system, modified to conform to individual requirements of the tracking system components. As these became known,

and after numerous conferences in which various compromises were reached, the present timing system was agreed upon.

Working from untried Minitrack drawings and informal sketches supplied by NASA-GSFC, production of 18 time standard racks was started. Numerous errors were found in the drawings as production progressed, but these were corrected as they occurred and did not materially delay delivery.

Detailed test specifications were prepared and verified by actually performing tests on the time standard at Cape Canaveral. Engineering assistance was provided during installation and testing at all sites, and trips were made to several sites to assist with unusual troubleshooting problems. Field reports were evaluated, and modification kits were provided where necessary to improve equipment reliability.

#### *Active Acquisition Aids*

The requirement for an active acquisition aid (AAA) was undertaken by Cubic Corporation under subcontract to Bendix Radio in an endeavor to supply an automatic angle tracker with  $\pm .5^\circ$  accuracy.

Because this system could not be categorized as an off-the-shelf item, an accelerated program was required to design, fabricate, and test the equipment. To further expedite the delivery of this system, use of surplus SCR-584 pedestals and existing circuit design were employed. Two other basic NASA requirements, phase comparison by passive techniques (use of hybrid rings) and correlation detection, were integrated into the system.

During April 1960, the first unit was shipped to the Demonstration Site. Subsequently, 17 additional AAA's followed, including three simplified systems using a new 8417 pedestal design.

In the late summer of 1960, Bendix Radio learned that an incompatibility existed between the telemetry package used as a signal source in the capsule and the AAA receiver. A technical solution was agreed upon, whereby the voltage-controlled oscillator and correlation detector of the AAA would be redesigned to achieve compatibility. This consisted basically of capability of the receiver to accept and track on FM signals with modulation indices greater than unity.

As the system progressed, and experience with the system increased, other deficiencies were un-

covered that made necessary a series of modifications. These modifications now total 31, and include such items as new boresight transmitters, time delay relays to protect power supplies, and servo system modifications to improve servo performance.

Cubic Corporation supplied trained field personnel at most sites to help install, align, operate, and instruct on the AAA. At the moment, they are being phased out of the program as need for their services diminishes.

Results of dynamic tests at several sites indicate good tracking performance, and general compatibility with the other systems in the Mercury complex.

Bendix conducted a system evaluation program on the AAA equipment at Eglin from December 1960 through February 1961. The intent of the program (in addition to system evaluation) was to ultimately arrive at a means of proper alignment and operational techniques that might help in improving the operation and reliability of the system.

#### *Installation and Maintenance Test Equipment*

This phase of the project comprised the selection and provisioning of adequate test facilities to permit proper installation, testing, and maintenance of the tracking and ground instrumentation system. It began with a study of the tests required for each unit of the communications, telemetry, acquisition, command, and radar systems, and a determination of the test equipment needed to make these tests. Quantities of each type of test equipment required were then established by analyzing the site configurations and estimating the amount of equipment sharing which would be practical, and also the amount of duplication which would be necessary for efficient operation.

In addition to conventional types of test equipment, special requirements were developed for noise figure and interference measurements. These required extensive engineering investigations. Other unusual requirements included free balloons carrying target spheres for radar tests, captive Kytoons carrying test transmitters for alignment of the acquisition systems, electrical and optical boresighting facilities for both acquisition and radar systems, and meteorological equipment to provide data for correcting radar outputs for atmospheric refraction.

To ensure continued accuracy of the test equipment furnished to each site, it was necessary to provide calibration facilities. After meeting with NASA and W.E. representatives, a selection of instruments was agreed upon and procured. These included a variety of apparatus which could be standardized by recognized laboratories and then used to calibrate the test equipment at the sites.

As the project progressed and the original estimates of test equipment requirements could be verified, or corrected, if necessary, the need for certain additional equipment became apparent. This equipment was procured as required. Considerable engineering effort was expended in developing test procedures to make most efficient use of available test equipment and to provide field personnel with technical assistance on test problems.

#### *Instrumented Aircraft*

The dynamic test phase required that each site be tested by using an aircraft instrumented to simulate an orbiting capsule. From the original concept of two aircraft with simple simulation equipment, evolved four aircraft systems with equipment more complex than that in the capsule.

One DC-3 (leased by Bendix Radio) and two C-54's (furnished by NASA) were instrumented and operated by Bendix Radio. The fourth set of instrumentation was fabricated by Bendix Radio and shipped to the Australian D of S which, with Bendix supervision, installed the equipment in one of its DC-3 aircraft.

The final form of the instrumentation included the basic capsule HF and UHF communications, telemetry, command, and radar beacon equipment — all furnished by NASA. These were integrated into an operating console which also contained audio input and output equipment, magnetic tape equipment for recording audio signals and providing simulated telemetry signals, extensive test equipment for verifying instrumentation performance, and primary power sources and controls. UHF and microwave antennas were installed on the aircraft, along with a high intensity xenon lamp system to facilitate optical tracking. Auxiliary power units were procured to permit preflight tests of the instrumentation, and VHF communications equipment

was furnished so that an independent voice communications link could be maintained from the aircraft to the ground station during test flights.

Tests of tracking performance of the radars and acquisition systems were accomplished by using boresight cameras mounted on the tracking antennas. Analysis of the films provided direct measurement of the angular tracking errors. The selection of the cameras, mounts, telescopic lens systems, and film processing and analysis equipment represented another significant portion of the total engineering effort. Closed-circuit television equipment was employed in conjunction with the motion picture cameras to give an immediate qualitative check of operation.

#### *Cabling*

The responsibility for the design of cabling between equipment supplied by various Team Members was assigned to Bendix Radio. Upon completion of the cable design study and the investigation of system cable requirements, a numbering system was devised to identify cable location, type (coaxial or multiconductor), and the supplying Team Member. To facilitate cable supply, a minimum number of cable types and configurations were selected. High-density neoprene-covered cable was selected for all outdoor and buried cable runs. Because of its low-loss and corrosion-resistant properties, one-half inch, neoprene-covered Foamflex was selected for use in critical RF circuits.

Because of the complexity and magnitude of system interconnection, cabling diagrams detailed over-all system interconnections only. Wiring charts were prepared to specify type, location, and termination of individual system cables. To facilitate supply and installation, it was determined that each Team Member should supply the mating AN and special connectors for equipment which they supplied.

At the beginning of detail design, the number of special multiconductor cable configurations was limited to 14. These types were used for all purposes, i.e., fabricated van cables, building-to-pedestal cables, and direct burial cables. Five of these same cable configurations were armor-covered for shipboard use. Standard lengths and configurations were established for the transmitter van and the Verlort van external cables to permit in-plant fabrication. The same type of

cable termination boxes and layout was selected for both the transmitter van and the Verlort van.

Preliminary installation wiring charts were prepared for the Demonstration Site cabling. Since these charts proved highly satisfactory at the Demonstration Site, they were employed for the remaining sites.

In-plant cable production consisted of transmitter van internal and external cabling, acquisition van internal and external cabling, and Verlort van external cabling. The primary consideration in cable design for the above units was standardization without sacrifice of system performance.

Delivery time for the majority of the installation materials was found to be exceedingly long compared to the time between selection (or definition of requirement) and the required shipping date. An accurate inventory of materials in stock and a flexible priority system for the designation of the site to which these materials were to be shipped, held work stoppage to a minimum.

Difficulties at each site were monitored through telegraph and weekly site reports. Other sites which would probably experience similar difficulties were notified to take corrective action immediately to prevent installation delay. Visits were made to seven sites during installation by a cable engineer to ensure proper installation and to provide on-site solutions to any problem areas. As difficulties appeared, modifications were added and system changes were made. Cabling diagrams and wiring charts were continually revised and sent to the sites so that uniformity and central control could be maintained for site cabling. This function facilitated the incorporation of modifications as they became necessary.

As the cable installation was completed, a cable engineer visited ten of the sites to prepare as-built drawings and cabling charts and to recommend improvements and clear discrepancies. At the completion of the visit to each site, the cabling information was revised to reflect the as-built condition of the site. The Bendix team leaders at the sites not visited, documented the changes at their sites which permitted as-built cabling information to be prepared for those sites. The cabling information was revised, reprinted, and distributed to the sites so that an accurate record can be maintained of future changes which may occur.

### **Mechanical Engineering**

Initially, considerable effort was expended to establish the requirements for equipment layouts and area requirements, and to delineate air conditioning requirements. This involved layouts of each building at the site where equipment was to be installed. Information required by B&R to design or modify the required buildings was compiled and submitted with layout drawings. Throughout the entire project, this activity was in process, and changes were made to drawings as new requirements were imposed.

The requirements for the transmitter vans were studied, and the specification was written. The specification took into account the space required, the type of construction, and the air conditioning necessary. After the contract was let, a mechanical engineer was assigned to the vendor's plant to assist in mechanical problems and to ensure that the van met the requirements of the specification. Necessary mechanical engineering assistance was furnished during installation of equipment.

Considerable information was required by B&R to design antenna and boresight towers which would not only support the equipment, but which would also be sufficiently rigid. A complete study was made of the antenna requirements, and sketch drawings showing the equipment configuration were prepared. This information was submitted and kept active as equipment requirements changed.

The following rack-mounted equipment required a major mechanical design and drafting effort:

1. Communication technician's console
2. Acquisition data console
3. Time standard rack
4. Voice receiver rack
5. UHF transmitter rack
6. Data switch unit
7. Terminal equipment rack
8. Monitor rack

Problems such as standardization of equipment mounting methods, equipment colors, and integration of purchased equipment were studied. Drawings were prepared and kept active by incorporating changes necessary during production and were corrected to show the final as-built or as-installed condition.

Mechanical engineering effort was required to install Mercury equipment on the Indian Ocean and Atlantic ships. The shipboard installations required particular attention to the design of shock and vibration mounting systems for each rack. A complete study of ship environment, equipment weight, and location of the center of gravity was made. An additional effort was required on studies for recommendations to solve vibration problems encountered on the tracking antennas.

Although many items were purchased for Project Mercury, mechanical requirements and liaison were required to ensure compatibility of purchased equipment with Bendix-Radio-designed equipment.

The mechanical engineering task planned under the initial concept of the instrumented aircraft was minor. Mechanically, the instrumentation consisted of an inflight console that contained about eight chassis to be used in the dynamic testing of ground station transmitter power and frequency output. The final instrumented aircraft was considerably more complex and consisted of preflight and inflight consoles to perform dynamic testing of capsule transmitting and receiving, monitoring and preflight checks on a complex telemetry system, and checks made with precise frequency measuring equipment. As the electrical scope increased, so did the mechanical engineering and drafting effort. Other factors that increased the mechanical effort were the variations introduced by fitting the equipment to two different types of aircraft, DC-3 and C-54.

Mechanical engineering and design were extensively utilized in the following areas:

1. Gathering data and physical dimensions on the various aircraft to be equipped;
2. Design of a shock and vibration mounted console to house and display various equipment chassis, and design of a support frame to house the console;
3. Design and modification of various units of the equipment such as battery boxes, attenuator chassis, and HF power indicator-attenuator chassis;
4. Design of the collapsible and rigid equipment dolly for preflight equipment, and of an equipment hoist for loading and unloading the preflight dolly and Solar gas turbine-powered generator into the C-54.

Along with numerous other design efforts, approximately 500 drawings were prepared for fabrication and documentation.

#### *Vehicle Communications*

NASA Specification S-45B definitized the maximum use of off-the-shelf hardware wherever possible. In the specific area of vehicle communications, the transmitters and receivers to be used were listed by name and military nomenclature as applicable.

Subsequent data package submissions to W.E., NASA, and Lincoln Laboratory detailed the manner in which existing hardware would be modified and integrated into the system requisite to the Mercury mission. These data packages also detailed the ancillary equipments required that were not available as off-the-shelf items and had to be designed and produced at Bendix Radio and subcontractor facilities.

Immediately upon receipt of each data package approval, all required purchased material was placed on order, and model shop work was started. Feedback information from SEG and SAG was reflected in design changes in the prototype models. The prototype models were submitted to engineering tests to confirm the finalized design and were then used by the test specification writers in preparing the factory procedures. Each production unit was submitted to both Bendix mechanical and electrical tests and W.E. inspection prior to shipment.

Expedited shipments to five priority sites were made, and rigid scheduling to the remainder of the sites resulted in long hours of work and continual problems of expediting long lead-time deliveries. Delivery of off-the-shelf military hardware became as much of a problem as finding sufficient time to properly design and build new hardware.

The Mercury engineering group was supported during assembly, checkout, and test phases of the program by field engineers soon to be assigned site responsibilities. These people, while familiarizing themselves with the Mercury systems, contributed invaluable assistance in preparation of suggested spares and site installation tooling lists.

Engineering support of installation and tests at the Demonstration Site followed. At this time, a decision was reached to prepare unit, subsystem, and system test procedures using a standard

format. Through the combined efforts of W.E., NASA, BTL, and Lincoln Laboratory engineers, this ambitious task was rapidly accomplished.

The latter stages involved introducing further sophistications and improvements into the system via the established change order and modification kit channels. Teletypewriter communication direct from the Project Mercury Office to each site was established, which provided a 24-hour answering service on all engineering problems. Engineering was gradually turned over to Bendix field engineering personnel who eventually took over full support of those sites under Bendix cognizance.

In summary, the following observations should be noted:

1. Military equipment, although requiring factory modifications, is now providing reliable performance in the Mercury system;
2. Commercial quality equipment required considerable field modification effort to provide performance comparable to the military equipment;
3. Engineering effort on Mercury-type endeavors followed the initial system to the field and required on-site engineering to resolve the many interface problems which arose as a system was integrated with those of other programs.

#### *Command*

The procurement of supposed off-the-shelf hardware again was a problem finally solved through the combined efforts of NASA, W.E., Bendix, the national ranges, and the equipment manufacturers. After many delays, equipment was diverted from other military programs and modified for Mercury use per Bendix specifications. The performance of the basic transmitting system has been very reliable. However, failures of certain critical system components, such as coaxial switches, have pointed up the need for 100% spares backup or redundancy in this system. Recent modifications to the systems have corrected these deficiencies.

Meetings with all interested parties were arranged by W.E., and these meetings were quite successful in resolving many of the interface problems arising from Mercury's maximum use of available national range facilities.

The design of coder controller systems, associated remoting systems, and command display outputs were definitized only after participation in several STG meetings. Compatibility with capsule systems dictated the final design of the coder controllers. Redesign of these units became necessary each time a test of the capsule clock systems indicated needed refinements. These units again were modified as additional command functions were introduced.

The coder controllers were delivered on schedule by a Bendix subsidiary contractor. Subsequent engineering investigations have resulted in further improvements in the operation and reliability of these units. Time did not permit the production of prototype units upon whose evaluation final production designs could be based. The prototype units are at the sites under continuous service.

#### **Spare Parts Provisioning**

The first meeting between Bendix Radio and W.E. to discuss provision of spares was held in September 1959. By January 1960, the first provisioning procedure was developed between W.E. and the Team Members, and provisioning was started. In April, NASA reviewed the provisioning procedure, which resulted in a completely revised procedure finally completed and issued on June 1, 1960. Prior to this date, however, (May 1960) one spare parts list, identified as Long Lead Spares Number 0100-1 for the Reeves Verlort radar had already been provisioned and ordered. Subsequently, the rest of the spare parts lists were prepared, and a conference was held in August at Wallops Island where the first completed lists were presented to W.E. and NASA for provisioning. These first lists were then re-worked as a result of this conference and were presented to W.E. and NASA for approval in October. They were returned to Bendix in November and purchase orders were issued December 15, 1960, with a required delivery date in May 1961. In the latter part of February, W.E. requested Bendix Radio to accelerate the target date for shipment of these spares to March 31. All suppliers were contacted even though this was relatively short notice and many items were not off-the-shelf items. As a result, about 50% of the lists were shipped by the first part of April, with the expectation of over 85% of the lists being

shipped by the end of April. Approximately 10% of the lists were delayed in provisioning and have an expected delivery date of May. Approximately 5% were expected to run on into June delivery because of procurement of very specialized items.

#### Instruction Books And Training Manuals

Early in the program, a series of publication conferences was held by W.E. and were attended by Team Member representatives. At these conferences, held in September, October, and November 1959, the requirements for instruction manuals were established. These requirements included the different types of manuals and the quantity of each.

In these conferences, it was established that Bendix Radio would provide two types of publications: equipment manuals and system manuals. Since the majority of the equipment being supplied by Bendix Radio was being purchased from various equipment manufacturers, the equipment manuals also had to be bought from these same vendors. Therefore, in October 1960, Bendix Radio prepared a purchase specification for commercial-type instruction manuals that stipulated specific requirements for the contents of these manuals. This specification later served as a model for other Team Members.

Bendix Radio was required to furnish a total of 153 different equipment manuals. Procurement in accordance with a tight schedule, compliance with specifications, handling and distribution, and revision to cover the latest engineering changes were among the problems encountered and overcome with the large number of vendor-furnished equipment manuals.

As soon as equipment requirements for the sites were established, work began on the preparation of system manuals. At a meeting of Bendix Radio and Bendix Pacific in December 1959, a complete and comprehensive outline for the system manuals was developed. (This outline subsequently served as a model for other Team Members.) At the outset, plans called for writing five system manuals, one each for the radar tracking system, the capsule communication system, the command control transmitting system, the timing system, and the acquisition system. Each of these was to describe the particular system for all sites. However, by August 1960 it became apparent that a single manual for the acquisition system would not be practical because of the

many ways this system differed from site to site. At a meeting among NASA, W.E., and Bendix Radio representatives held in August 1960, it was decided that ten separate acquisition manuals would be prepared.

All of the system manuals were first sent to the sites in preliminary form. This procedure was followed for two reasons. First, a preliminary issue of any manual could be prepared more speedily than a final issue, allowing the technical information to be at the site by the earliest possible date. Second, it allowed time for incorporating later engineering modifications and site changes into the final issue.

Delivery of the majority of all the final manuals required, both system manuals and equipment manuals, has been accomplished. It is expected that by June 1961 all final issues of all manuals will be delivered.

#### Site Implementation

Bendix Radio Field Engineering joined Project Mercury in the fall of 1959. The first responsibility for this department was to assist in site surveys. During the early phase, Field Engineering personnel worked with design engineers on site layouts and site problems, providing the field engineers with valuable background experience on the equipment as well as giving needed assistance on design work.

As of November 1959, there were ten field engineers assigned to Project Mercury. This figure continued to grow as the site installation effort increased until a peak force of 221 engineers and technicians were assigned to the project by January 1961. Present activity consists of M&O responsibilities, clearing deficiencies, and technical monitoring of the sites.

Early phases of the program revealed a requirement to train field personnel on many types of equipment. To meet this requirement, schools were established in Baltimore and personnel were sent to other companies to learn installation, testing, and operation procedures. In June 1960, a requirement arose to supply test equipment calibrators at each Mercury site to support the installation testing phase. To meet this requirement, field engineers with calibration experience were selected and assigned to the Bendix Radio Measurement and Standards Group to familiarize this group with the test equipment and calibration procedures to be used.

Another task assigned to field engineering personnel was to assist in writing test procedures, equipment manuals, and test equipment calibration documents.

## BENDIX PACIFIC

### Program Implementation

#### *Initial Organization*

The scope of Project Mercury and the responsibility of Bendix Pacific established in the original Mercury proposal were used as the basis for arranging an organizational structure most suitable to fulfilling the program requirements at Bendix Pacific.

With full understanding of the requirements, the Mercury Project Office was organized under the direction of the program manager. Departmental heads responsible directly to the program manager were assigned to each of the functional divisions of the program. A smooth flow of communication concerning all phases of the program was thus provided between the program manager and Bendix Pacific management and between the program manager and Mercury Team Members.

### Program Management

Direct control of planning and scheduling was accomplished for all engineering, program management, purchasing, field service, quality control, contract administration, publications, and associated activities through the operations performed in the Mercury Project Office.

Systems engineering responsibilities were delegated to a systems engineering manager who provided direct control of the Digital Data Processing, Telemetering Receiving, and Telemeter Display engineering divisions. He provided supervision and assistance in all activities involving the planning and scheduling of effort for the three engineering divisions. Key personnel from the three sections met regularly with the systems manager and the program manager in committee sessions and individual meetings to outline plans, report and discuss progress, resolve engineering difficulties, and schedule in complete detail all engineering areas of the program. Close liaison was therefore maintained between the specialized engineering sections and the program manager.

Other program areas, such as production planning, inspection, purchasing, contract administration, financial control, publications, quality control, drafting, reliability, spares provisioning, and field support engineering were either directly represented in the Mercury Project Office or were represented through efficient communications link with the program manager backed up with frequent project meetings.

In addition to the departments set up specifically for Project Mercury, existing specialist groups at Bendix Pacific were frequently called upon to assist in the program by providing various services, such as conducting detailed studies and compiling various procedures.

#### *Initial Equipment Requirements*

A prime accomplishment of the Mercury Project Office at the outset of the program was the development of proposed system parameters for the Bendix Pacific equipment furnished to each of the ground instrumentation sites.

A further breakdown of major equipment items was compiled and each item investigated with respect to design requirements, reliability, performance, availability, and system compatibility. Careful consideration was given to design and delivery requirements when it was necessary to make decisions regarding procurement or construction of various equipment items. In every case, specifications were prepared and submitted to W.E. for approval.

#### *Detailed Scheduling*

Paralleling the engineering design phase, detailed planning was performed by the Mercury Project Office staff under the supervision of the program manager for all program areas including departmental budgeting, detailed design engineering, procurement, production, test, and shipping. Specially designed bubble charts were prepared for all areas to ensure that production completion dates would be met. Expediting long-lead items became a major effort and sometimes required visits to vendors to coordinate equipment delivery dates with in-plant completion dates.

Through the use of time-planned charts, the program manager was able to follow the daily progress of specific program areas. Immediate

action was taken when it was anticipated that a slippage in schedule might occur because of late deliveries or a delay in equipment assembly.

To comply with master schedule delivery dates, it was determined that a complete set of equipment would be required every two weeks. Since many items required modification to meet individual site requirements, special expediting groups were assigned to control the effort required to furnish the equipment according to schedule. Early delivery of the Wallops Island systems provided a means to check the original assembly procedure which was modified for subsequent site shipments.

Manpower and material control schedules were used to integrate engineering operations for procurement, manufacturing, and assembly planning. Each task assigned to an engineering section was outlined in full detail to permit effective coordination within that section and with other areas of the program.

Manpower loading charts were used to effect a proper distribution of trained personnel. The charts were continuously adjusted to meet immediate and future requirements, which were changed throughout the program to conform to the many changes in scope.

#### *Specifications*

Initial program effort in the area of specifications involved the participation of Bendix Pacific personnel in the preparation and evaluation of Specification S-45A and the generation of new systems requirements. Data packages and information for the Project Mercury Ground System Analysis Report to NASA were also generated during the early stage of the program.

In early November, an advance copy of Specification S-45B which incorporated all program changes and developments to that date was received at Bendix Pacific. This revised specification was reviewed and analyzed with possible corrections and additions reported to Bendix Radio for further discussion and presentation to W.E.

On February 10, 1960, Bendix Pacific offered acceptance of Specification S-45B with the revisions attached, as prepared by W.E.

#### *Technical Approvals and Development Authorization*

Approvals for the majority of basic scope telemetering receiving and display items of equipment were categorized at a NASA meeting on September 21, 1959, at Langley Field.

Program activity accelerated to full speed on receipt of equipment approvals from August through December 1959.

Based on authorization to proceed with the design and fabrication of added scope equipment required at Cape Canaveral and Bermuda, Bendix Pacific launched an intensive drive to fulfill the increased system requirements so that, despite late changes, target dates could be met.

On April 8, 1960, formal authorization was received from W.E. permitting Bendix Pacific to proceed with the development of special flight controller trainer equipment to be installed at Cape Canaveral and Langley Field.

#### *Quality Control*

In July 1959, a quality control coordinator was assigned to Project Mercury from the Bendix Pacific quality control department. His duties in the early phase of the program involved the planning and scheduling of quality control efforts at subcontractor plants. As the program progressed, vendors were evaluated by quality control surveys, which were conducted by Bendix Pacific quality control personnel temporarily assigned to the vendor facilities. Quality assurance was maintained at the vendor plants throughout the major procurement phase of the program, which terminated in July 1960. From that time, the in-plant quality control department assumed responsibility for quality assurance.

#### *Reliability Test Program*

A reliability test program was organized to determine reliability standards for the Bendix Pacific-furnished equipment at the sites. Equipment malfunctions were recorded on failure reports at the sites. Defective part tags were attached to components causing equipment failures. The components and the failure reports were then forwarded to Bendix Pacific for analysis and testing. Results were returned to the originating site and, when applicable, to the component subcontractor, thus providing a

closed-loop method of recording data on equipment failures.

### **Modification Board**

An engineering change board was organized in September 1960 to exercise control over all Bendix Pacific equipment changes requested by W.E., in-plant engineering, or field representatives. Engineering change procedures were formulated covering the incorporation of all changes by modification kits and associated drawings or in-plant modifications. The board assumed responsibility for determining the most suitable approach for individual problems with regard to design, part procurement, fabrication, and time considerations.

The modification program went into operation in October 1960 and continued with kits constructed and forwarded to the sites, as required, throughout the duration of the contract.

## **Systems And Other Engineering**

### **Digital Data Processing**

In the area of digital data processing, program efforts included analysis of system specifications, system engineering, and the detailed design, procurement, and fabrication of equipment items for the radar digital-to-teletypewriter conversion subsystem and the high-speed radar data transmission subsystem. Identical efforts were required for a telemetry/event buffer and a telemetry/event transmitting buffer both of which were subsequently added to the program requirements.

Approval was received from W.E. in November 1959 for design and fabrication of the digital-to-teletypewriter conversion subsystem. During the design stage, a plan was formulated and submitted to W.E. for demonstration of the subsystem at Wallops Island. The plan included demonstration of the equipment self-checking abilities, long-term stability, conversion accuracy, and operation under static and dynamic conditions.

In March and April 1960, quality and operational tests were successfully completed on the conversion equipment in the Bendix Pacific data processing laboratory.

Dynamic tests conducted at Wallops Island revealed the requirement for minor equipment

modifications to ensure more efficient operation. After modification of the equipment, the subsystem was successfully demonstrated, and the remaining 15 digital-to-teletypewriter converters and associated equipment were subsequently shipped, with modifications installed, to the respective sites.

On receipt of approval in November 1959, design and fabrication activities for the high-speed data transmission subsystem began. Various changes to the original specification were incorporated during equipment design and fabrication, such as a requirement for the Bermuda data receiver to produce either an 8-bit serial or a 36-bit parallel output. A problem concerning excessive dropout at the Bermuda tape/recorder reproducer discovered during the static laboratory testing at Bendix Pacific was investigated and an appropriate equipment modification was added to restore normal system operation.

On successful demonstration of the equipment at Wallops Island, the high-speed data transmission equipment was shipped to Cape Canaveral and Bermuda.

The telemetry/event buffer for the Bermuda installation was started in February 1960. Minor design changes were incorporated during the manufacturing period to conform to revised NASA specifications. The completed buffer was shipped in May 1960, and a design engineer was assigned to the site to ensure system compatibility with the telemetering and computer interface.

During the last quarter of 1959, Bendix Pacific representatives discussed systems design specifications with NASA and The Burroughs Corporation for a telemetry/event transmitting buffer required at Cape Canaveral. In February 1960, launch computation requirements were discussed with W.E. and IBM representatives in an effort to resolve data conversion problems concerning the buffer. On receipt of synchronization information from IBM in March, design of the unit was finalized. In May, a major modification of the buffer was incorporated, and in June the unit was shipped to Cape Canaveral. The telemetry/event transmitting buffer was designed, fabricated, modified, tested, and accepted in 112 working days.

Other items of equipment which came under cognizance of the digital data processing section included digital clocks and a retrofire time

change mechanism for use with the telemeter display equipment, coaxial switches required at the FPS-16 radar installations, digital synchro data transmission systems, a nixie remoting indicator and associated film processing unit for the FPS-16 radar at Bermuda, and equipment required to prepare simulation tapes. Modification kits were also designed and installed when required for these items.

On the receipt of authorization to proceed with Phase I of the radar data analysis program (MER-70), 11 radars at six sites were investigated. Results of the preliminary investigation and suggested techniques for checking the radars and associated data processing equipment were compiled and presented to W.E. in a detailed report.

Approval was received for the design and fabrication of equipment for the MER-70 program and also for checkout of the radar outputs at the sites. Experimental drawings and equipment designs were finalized in December 1960, and breadboard models were used for static checkout at Bermuda.

Test procedures for the program were prepared in January. Field evaluation of the procedures designed to check out the entire radar digital data systems was conducted at the Point Arguello FPS-16 radar and the Bermuda Verlort radar during January and February.

The program progressed according to schedule in March, with three teams initiating radar data analysis programs at Bermuda, Kauai, and White Sands.

As of April 15, all equipment for the program had been shipped to the sites. The equipment includes items for checking out Verlort and MPQ-31 output displays, FPS-16 and MPQ-31 encoder simulators, and three complete sets of radar data analyzer equipment.

Testing of the FPS-16 radars has been completed at Kauai, White Sands, and Woomera. In April it was necessary to reschedule MER-70 tests at sites employing Verlort radars to allow for replacement of the Wayne-George encoders. As a result, the program has been extended to June.

### *Telemetering Receiving*

The telemetering receiving equipment was designed to receive PAM/FM signals from the capsule, to demodulate, separate and record these

signals, and to supply the recovered data to display equipment.

The telemetering receiving stations were designed in five configurations and involved the procurement or design of 60 major equipment items. One hundred and sixty-two equipment cabinets including four different configurations were designed and fabricated to house telemetering receiving equipment.

Early design efforts were concentrated on the establishment of system requirements and the review of available commercial equipment for procurement purposes. Equipment specifications for all except three procurement items were completed by the end of December 1959. The major procurement items included telemetering receivers, decommutators, recorders, and monitoring and test equipment. Although these items substantially complied with project requirements, it was necessary to perform extensive evaluation testing and, especially in the case of receivers and decommutators, furnish modifications through the combined efforts of Bendix Pacific and equipment subcontractors.

Project specifications and engineering evaluation of the system established the requirement for the design of over 15 new items of equipment. New design items included: Signal Strength Mixer TGM-103, Instrumentation Timing Conditioner TGC-102, Power Supply Sampling and Control Unit TSP-104, annotation units, analog and event buffers, display input control panels, and various indicator and switching panels.

After basic design and procurement requirements were established, system documentation was initiated. This phase of the program consisted of generating parts lists; assembly drawings; cabinet, intercabinet, and interface wiring diagrams; and cabling diagrams. Inspection and test procedures covering both vendor and Bendix Pacific equipment were written. A demonstration procedure was developed during February and March 1960. The demonstration procedure provided the basis for the subsequent development of firm system operating procedures.

During the installation and checkout phase of the program, engineering representatives were assigned to the various sites to assist and direct the activities of installation and maintenance personnel. To ensure a high level of system reliability, failure reports and recommendations for equipment modifications were reviewed and re-

sulting modifications were implemented. Several of the modifications were based on experience at sites where equipment was installed early in the program; thus, it was possible to incorporate the modifications into several of the stations prior to shipment. Other equipment changes were made as part of the field modification program, which is still in process at Bendix Pacific and at the sites.

Additional telemetering equipment (not part of the telemetering receiving system, but furnished as required equipment for the program) consisted of the capsule telemetry simulator used in the airborne dynamic test program, the data reduction system for postflight analysis of capsule magnetic tape recordings, and instrumented tapes used in equipment checkout at the various sites.

#### *Remote Station Displays*

Three telemeter display plans were submitted to W.E. and NASA by Bendix Pacific engineering representatives in October 1959 at Langley Field. The plans were developed with assistance from medical and human factor engineering consultants. A compromise which involved various deviations from the originally proposed display plan was subsequently formulated and submitted to W.E. for approval in November.

Also in November, preliminary drafts of new and revised specifications describing various display items were generated.

New layouts of the display arrangement were prepared in December and a partial mockup of the display console was fabricated to simulate the revised concept requested by NASA. A revised layout drawing incorporating the requested changes was prepared and submitted to W.E.

On receipt of approval for the telemeter display console, electrical and mechanical design and the formulation of detailed electrical and mechanical drawings and wiring diagrams were initiated. Final mechanical design and detail engineering were completed in April, and fabrication of the first unit was completed in May. Fabrication of subsequent units was transferred to the Bendix Pacific production department.

Authorization was received in February for the design and fabrication of a fine monitor cabinet for Cape Canaveral. Fabrication of this cabinet, and an additional similar cabinet (capsule clock cabinet) for Bermuda, was completed in June.

Additional equipment designed and fabricated in the telemeter display section included the flight controller trainers for Cape Canaveral and Langley Field. All trainer equipment was completed and shipped to the respective sites by August 1960.

#### **Production**

Production requirements required extensive planning and scheduling on the part of the production staff in conjunction with the Mercury Project Office and the three engineering divisions responsible for equipment design. A production coordination conference with W.E. in December 1959 resulted in the establishment of many constructive measures, which were incorporated in the existing Bendix Pacific production program.

#### *Scheduling*

In the process of preparing detailed schedules, several problem areas were investigated to ensure successful delivery of equipment. Initial production planning indicated that additional floor space would be required for equipment assembly, checkout, and system test of site equipment. Construction began in November 1959 on an addition of 24,500 square feet of floor space adjoining Bendix Pacific Plant No. 4. The new area was completed in February 1960 according to schedule, and production activities began immediately.

Changes, such as requirements for event buffers and fine monitor equipment for Cape Canaveral and Bermuda, modifications, and many system improvements, required extensive planning and redirection of efforts to ensure on-schedule delivery of equipment.

#### *Production Techniques*

An analysis involving the nature and volume of equipment required, program schedules, and cost factors prompted a decision to perform all sheet metal fabrication in the Bendix Pacific facility. This procedure permitted complete control of efforts and enabled the production department to meet schedule requirements on planned component, subassembly, and final assembly stages of the material flow pattern. Also, it was determined that a more sturdy, higher quality standard equipment rack should be used

for the Bendix Pacific-furnished equipment. A modification of the original design was performed utilizing existing tooling and equipment. Consequently, a superior cabinet was produced at considerable saving over the cabinets which were commercially available and acceptable.

In cooperation with the engineering departments, a cabinet block and wiring assembly technique, which greatly expedited production, was developed. This improved approach allowed prefabrication and assembly of internal single cabinet and multiple cabinet wiring and permitted installation prior to the grouping of cabinets and electronic chassis. By using the new system, installation of a chassis or subassembly into a cabinet required merely attaching the chassis to pre-mounted slides and connecting the plugs into the receptacles provided.

Because two to five cabinets had to be physically fastened together in a block assembly, a problem concerning the handling and moving of equipment blocks during the various production operations developed. A technique that solved the problem was developed, using shock and vibration rubber-wheeled pallets of required sizes to accommodate empty cabinets or cabinet blocks. It was thus possible to move the equipment from station to station with full physical protection.

Although all equipment blocks for the ground instrumentation sites perform basically similar functions, the physical arrangements vary such that a standard production line procedure could not be employed until after fabrication of items for the first six sites. Two additional sets of equipment required for the shipboard installations also required individual fabrication. Before design was finalized, Bendix Pacific consulted with W.E., the Naval Electronics Laboratory, and various manufacturing firms specializing in shock and vibration isolation mounting systems. Subsequently, the two installations were completed to the proper environmental specifications.

#### *Delivery*

Bendix Pacific designed, developed, procured, fabricated, assembled, tested, and delivered 19 stations of electronic equipment, including two data processing stations required at Eglin and White Sands, from August, 1959 to September 1960. The first station was shipped on schedule to the Demonstration Site on April 15, 1960. The

last complete station was delivered in September just 5½ months later. A typical station consisted of from 12 to 18 standard racks of equipment, plus a three-position display console.

Concurrent with original equipment production, many additional equipment items were produced and modifications incorporated in time for delivery with the stations.

In January 1960, Bendix Pacific selected a vendor for packaging and crating equipment for overseas and domestic shipment. A packaging and shipping specification for overseas equipment transport was prepared in February in cooperation with the packaging and crating vendor. All equipment was packed for delivery in wooden containers, mounted on vibration and shock isolation systems, and completely enclosed in a vacuum bag, which afforded maximum environmental protection. All equipment was delivered to the domestic and overseas locations on schedule with a minimum amount of normally expected damage.

#### **Procurement**

A list of critical and highly-critical items that required immediate purchase in September of 1959 was prepared and discussed with W.E. Approval was received from W.E. on October 6 for a substantial number of telemetering equipment items, and procurement was immediately initiated for these Category A items. Additional procurement activities were accelerated for other equipment items on receipt of supplementary funding and technical approvals from W.E. in November. When formal vendor bids expired due to approval delay, requests were issued to all potential vendors for price confirmation and new delivery dates.

In December 1959, a conference with W.E. at Bendix Pacific relative to coordination matters involving the procurement, production, scheduling, and accounting phases of the project resulted in the establishment of many constructive coordination and communication measures.

Early in 1960, major vendors whose delivery dates were unsatisfactory were visited by Bendix Pacific and W.E. representatives to negotiate improvement in delivery schedules. These expediting efforts resulted in generally acceptable promises and subsequent delivery of purchased items for Wallops Island.

In June 1960, purchase orders for all major items of new equipment required were placed, and by August 50% of the new vendor-purchased items were received at Bendix Pacific. The remaining items were received in time to meet the scheduled site shipping dates.

### Spare Parts

As a result of the spare parts procedure agreed on at the conference held at W.E. in November 1959, Bendix Pacific initiated implementation of a special group responsible for spares analysis, electrical accounting machine (EAM) card processing, vendor contracts, and documentation. The first spare parts recommendations requested and received from vendors in conformance with the established procedure were evaluated with respect to site and depot requirements.

In December 1959, a copy of the Spare Parts Selection Procedure was received from W.E. and a study of spare parts problems was initiated, the results reviewed, and a new procedure introduced at spare parts provisioning meetings with W.E. and Bendix Radio in mid-1960.

Production parts lists for parts peculiar items (those items or detailed components peculiar to specific assemblies) were submitted to Bendix Radio and W.E. for approval in July 1960, as were the first common items lists which were prepared for consolidation with other Team Members to avoid duplication of materiel.

In September, the recommended spare parts lists for Bendix Pacific-furnished equipment and vendor-purchased items were completed for all original scope items. Lists for the added scope items were subsequently prepared and delivered individually.

To replace the equipment damaged by a power surge on the Indian Ocean Ship during checkout procedures, an emergency replacement parts package was procured and forwarded in December.

Purchase orders for the first two lists of parts peculiar items were placed in December for 41 equipments and, in January, approval for the third Parts Peculiar Items List was received and purchase orders were released.

The first issue of the Bendix Pacific Group II Common Items List was completed, approved, and the purchase of all materials initiated in January 1961. Subsequent issues of the provi-

sioning list including all other Team Member requirements was submitted for approval on receipt of information from Team Members in February and March.

Western Electric requested Bendix Pacific to provision and procure certain spare parts (emergency items) and deliver them to Bermuda, Cape Canaveral, Grand Canary Island, Muchea, Woomera, and the shipboard installations on a high-priority basis. Fulfillment of this special requirement was given priority over other spare parts activities and, through the use of special handling techniques, the parts were delivered within the customer specified deadlines.

Final shipment of all parts peculiar items was accomplished in May 1961.

The consolidated Group II Common Items List, Issue No. 1, covering the Bendix Pacific primary equipment, consisted of approximately 1700 different items. Orders were placed for all items and the major portion was received in March. Final shipment to all sites was accomplished in May. Group II common items for other Team Members were also shipped in May.

Two Bendix Pacific representatives attended the provisioning conference at W.E. on March 21 to review the spare parts portion of the program, considering the provisioning of additional quantities of items in certain areas, and establishing new requirements not previously considered, such as the simulation systems for Langley and Cape Canaveral, the digital synchro data transmission system, the airborne trainers, and various items of test equipment. Spares lists for the Bendix Pacific modification kits were prepared and were also reviewed at the conference.

### Instruction Books And Training Manuals

Work on equipment and systems manuals was initiated in October 1959. Following the determination of format and content requirements, which were established during the publications and training conferences held at Bendix Radio and W.E. in November, preliminary outlines for Bendix Pacific system manuals were written.

A Bendix Radio representative visited Bendix Pacific in January 1960 to coordinate revised system manual concepts. Full agreement was reached with regard to format, style, and coverage. A recommendation for certain changes in the outline, which was developed during the

previous publications conference in November, was submitted to W.E.

Bendix Pacific representatives attended a conference at W.E. in April 1960 covering all phases of the publications program, a review of progress achieved, and the scheduling and distribution of manuals. It was concluded that delivery of final instruction books should coincide with the start of the technical monitoring phase at the respective sites and that instruction material in preliminary form would be provided for the installation of equipment at the sites.

Two sets of instruction manuals for 24 major items of equipment were forwarded with the equipment shipped to Wallops Island in April. The remaining handbooks arrived at the site prior to equipment checkout.

The wiring of instruction books for 50% of the equipment items and the preliminary draft of the digital data processing system manual was completed in May.

By July 1960, preparation of instruction manuals for 20 manufactured items was completed, and instruction handbooks for 27 vendor-purchased items were received.

Preparation and finalization of systems and equipment handbooks continued through October; in November all handbooks were completed except for MS-123, ME-303, and ME-409, which were completed in the following two months. A modification and change program was established during the last quarter of 1960 to update in-plant and vendor handbooks.

Instruction handbooks were completed in December for new-requirement equipment. Among these were handbooks for the nixie indicator remoting system and the display equipment power supply assemblies.

In January 1961, the preparation of rough drafts covering equipment designed for the MER-70 program and investigation of a revision to ME-330 *Special Equipment Manual* to accommodate the MER-106 program were initiated. The MER-70 handbooks were completed in May.

The modification program is still in effect and will continue with changes processed as required to reflect equipment modifications in the field. Change pages, addenda, and complete revisions will be continuously forwarded to all applicable sites and agencies for attachment to, or replacement of, Bendix Pacific-prepared and vendor-purchased manuals. As part of the program, com-

plete revision pages to systems handbooks MS-106 and MS-105 were distributed in May.

### Training

Study of training concepts and needs, and the development of on-the-job training guides was initiated in September 1959. A tentative outline of the Bendix Pacific guides was forwarded to W.E. for comment in October. The plan included separate training guides for each of the three systems.

Four preliminary on-the-job training guides and preliminary operation sequence plans were completed and distributed in February 1960. Final issues were distributed to the sites in July, including question-and-answer sheets and on-site evaluation procedures.

The in-plant training program for site engineering support personnel was rescheduled in accordance with modified on-site requirement dates. The first of seven courses conducted at Bendix Pacific began in March 1960. The remaining courses were staggered to correspond with the requirements of personnel assignment to the respective sites. Indoctrination courses were conducted by the cognizant design engineers in three groups. One covered the over-all Mercury ground instrumentation system and the Bendix Pacific telemetering and digital data processing systems in general. The second group included the installation, test, operation, maintenance, and acceptance procedures for the telemetering system at the early sites. The last group handled the same type of information with regard to the digital data processing system. Thirty students attended the first classes, with NASA, W.E., Cape Canaveral, Point Arguello, and Bendix Radio personnel participating in the first three weeks of training.

Following completion of the first six-week support engineer training course, a group of 12 field service personnel assigned to the Bendix Pacific-furnished ground instrumentation stations graduated on May 13. The graduates were processed for preparation for their departure to the sites. The second and third six-week courses were attended by contractor representatives from Point Arguello, Cape Canaveral, White Sands, and D of S personnel.

On-site maintenance procedures for all sites were forwarded for incorporation in W.E.'s on-site maintenance procedures in November 1960.

## Site Implementation

Initial site planning activities included gathering information from various sites by field study trips. Preliminary site block diagrams and equipment listings were obtained as a result of these visits. A team briefing in August 1959 at Eglin and discussions with W.E. and NASA representatives in September provided additional site planning information necessary for determining equipment implementation at the sites.

Preliminary lists of data processing equipment requirements for the individual sites were revised to reflect new concepts agreed on at a conference at Langley Field in September. Other decisions resulting from the conference were the elimination of Project Mercury installations at Guadalcanal and Grand Bahama Island and the substitution of permanent buildings for trailer vans. These changes necessitated revision of site equipment requirements for the telemetering receiving and telemeter display equipment. In October, revised site layouts of Bendix Pacific-furnished equipment were forwarded to B&R for inclusion in the permanent building layout diagrams.

At engineering systems committee meetings held at W.E. in October, typical equipment layout and space requirements were established for 12 sites; building layouts at Cape Canaveral and Bermuda were reapportioned for a more adequate equipment layout; and the Grand Bahama was reinstated. All of these changes caused considerable revision of schedules and cost estimates.

In January 1960, field engineering personnel participated in implementation team visits to Grand Turk, Grand Bahama, and Guaymas, and in an inspection of a typical ship for shipboard installation.

In February, major site implementation efforts included design changes required for a relocation of equipment at Cape Canaveral and downrange sites based on a change in system scope. Revised site drawings prepared by W.E. and B&R were reviewed and annotated as to optimum equipment layout for Bendix Pacific equipment.

Bendix Pacific representatives attended site implementation conferences in March at W.E. and Bendix Radio to discuss general mechanical installation problems at all sites. Meetings concerned with interface cabling, cable raceway, equipment location, and grounding problems at Cape Canaveral were attended by Bendix Pacific

personnel, as were conferences regarding the solution of integration problems at Point Arguello.

In April, Bendix Pacific representatives participated in conferences at W.E. and Bendix Radio concerning interface and cabling problems, particularly regarding Wallops Island and five other sites scheduled for early equipment delivery.

The Bendix Pacific telemetering receiving system and digital data processing equipment arrived at Wallops Island on April 18, 1960. The telemeter display console base was damaged in shipment and was replaced prior to installation. Photos of the damage incurred were furnished to the shipper for analysis to prevent possible recurrence of the incident. Bendix Pacific system engineers were assigned to the site to coordinate equipment arrival and supervise the installation of the systems. Demonstration procedures including static and dynamic system tests were successfully completed at Wallops Island with engineering personnel performing the systems demonstrations.

Recommended procedures for handling, unloading, unpacking, moving, and installing Bendix Pacific equipment were prepared in May. Also during May, site layout drawings, showing Bendix Pacific equipment locations, were revised to include information released by W.E. and B&R, and a guide for field support personnel covering the general procedures recommended for duty at remote locations was prepared.

In June, field service personnel were assigned to Wallops Island, Bermuda, Cape Canaveral, Grand Bahama, and Grand Turk. Field service engineers at Wallops Island conducted approximately 22 semiofficial tests, which were monitored by representatives of W.E. and NASA. Field service engineers compiled detailed procedures covering new test procedures specified by NASA. Wallops Island was also utilized as an operation evaluation and improvement station for analysis of system modification requirements.

Operator procedures for Wallops Island, Bermuda, and Cape Canaveral were prepared and published as separate documents, and equipment check lists were prepared and submitted to BTL as part of the Grand Canary Island operations plan review.

Bendix Pacific engineering personnel were assigned to GSFC for one week to install and test

the high-speed data transmission equipment. Combined efforts between Bendix Pacific and IBM engineering personnel resulted in reception of a 1000-bits-per-second data transmission over the IBM real-time channel from Wallops Island.

Digital data processing equipment arrangements, modifications, and test procedures for Wallops Island were completed in July. During the same month at Bermuda, all telemetering system and digital data processing equipment was received and installed, and a Bendix Pacific engineering representative successfully demonstrated operation of the telemetry/events buffer for IBM personnel. At Cape Canaveral, all digital data processing and telemetering receiving equipment was received. The telemetry/event transmitting buffer was installed, tested by Bendix Pacific, and accepted by IBM.

During August, all site layout drawings were

completed and forwarded to Bendix Radio and W.E. The flight controller trainer and auxiliary equipment arrived at Langley Field and was installed and tested during August. Two field service engineers were assigned to Langley Field for operation and maintenance of the data reduction equipment, which was installed on August 15.

From September 1960 through April 1961, Bendix Pacific engineering representatives and field service personnel engaged in extensive site activities including the three-phase (MUT, MST, and MDT) testing program, the incorporation of field modification kits, and various actual tracking and monitoring of vehicle launches. As a result of reliability analysis and design change requests, over 125 field modifications have been implemented by Bendix Pacific to date.

## BURNS AND ROE, INC.

Burns and Roe was responsible for design, engineering, purchasing, transportation and warehousing, logistic support of all non-C&E equipment, construction management, and preliminary operation of non-C&E equipment.

### ENGINEERING AND DESIGN

Engineering and design was under the direct supervision of the project engineer. Stations with geographical or scheduling similarity were grouped together under the direction of a site coordinator. Site coordinators were responsible for the design and engineering efforts of their assigned sites.

The design of all range facilities proceeded under guiding principles of maximum reliability, lowest cost consistent with timely delivery, mobility for future relocation, and logistical considerations governed by available sea and air transportation. Another primary consideration was the economic use of on-site native skills and labor forces.

Early in the project, it was decided to utilize maximum standardization and prepurchase of major equipment to meet the schedule. To implement this policy of standardization, it was decided that diesel generator sets, air-handling

units, prefabricated buildings, refrigeration machinery, oil transfer pumps, and similar items would be purchased in bulk through competitive bidding. This decision required that the basic designs of all stations proceed on a concurrent basis.

This standardization and method of bulk purchasing minimized costs and simplified the provisioning of operational spare parts required for each of the global sites.

Preliminary layouts were prepared for each station and issued to W.E. and Team Members for comments. As soon as B&R received comments from its associates and concurrence in the design approach, detailed designs were prepared for individual stations.

A standard criteria for the tracking network was that the stations be designed, constructed, and in operation in a specific sequence.

### SITING

During initial conferences, preliminary locations of acceptable sites were selected. Area determinations were based on the range capabilities of the radar equipment, characteristics of communications and tracking facilities, planned orbital paths, and the necessity of maintaining contact with the capsule.

Final, precise location was established after thorough investigation by siting teams, consisting of representatives from NASA, W.E., Bendix, and B&R. The representative of each Team Member was responsible for gathering necessary information to fulfill their responsibility. The over-all siting team selected a definitized location to satisfy all project criteria.

Because of the global nature of the project, many sites were selected on foreign soil. Negotiations with the governments involved were carried out by NASA, through the U.S. State Department.

Management teams, representing NASA, W.E., and B&R, visited certain foreign sites to pave the way for the working teams. Local authorities were contacted and the objectives of Project Mercury were explained.

Four technical siting teams were then assembled, consisting of engineers with experience in site development, logistics, electronic systems, and design and construction. NASA, W.E., Bendix, and B&R staffed these teams, which were dispatched to the various sites to finalize location and to collect all necessary information for detail design, construction, and operation.

The data which these teams gathered provided fundamental design information in sufficient detail to minimize changes. Much information was collected, including:

1. Subsurface information;
2. Local facilities for transportation and handling of equipment;
3. Availability and practicability of local utilities, including transportation, housing, and medical facilities;
4. Availability of construction material;
5. Availability of local subcontractor organizations and construction labor forces;
6. Climatic and meteorological information;
7. Interference and line-of-sight problems.

During the siting trip, the working team arranged for all surveying required to locate the facilities in conformance with the actual topography, and in accordance with established criteria.

## PURCHASING

The B&R Purchasing Group was assigned responsibility for purchasing all major items of

equipment and letting all subcontracts. All construction subcontracts were solicited by this group. Qualified bidders were selected for each site and were sent a package of construction drawings and specifications, with a request that they submit sealed bids by specified dates. All bids which were received were opened on these specified dates by the purchasing agent and read in the presence of representatives from W.E. and B&R. The successful bidder was determined after a careful analysis. The successful contractor was notified by telephone or telegram; the contract was confirmed by a letter of intent and, subsequently, by a B&R purchase order.

Because of complications arising from remoteness, faulty communications, and poor response, it was necessary to make personal contacts with bidders in Nigeria and Zanzibar.

On completion of preliminary design criteria, requisitions were prepared and quotations requested for prepurchased items of structural facilities and mechanical and electrical equipment. After analysis of these bids, letters of intent were issued to secure the earliest possible delivery dates. All major and critical items were expedited by visits to the vendors' shops. Expediting was also carried out by the Project Manager's Project Coordination Group. Overseas shipment was handled by a section of the Project Accounting Group. A crash purchase program was established for Bermuda. It was decided that B&R would not sublet the mechanical and electrical work; B&R performed the purchasing functions normally handled by the various subcontractors. Field purchasing personnel procured all items which were readily available at the site, as well as the rental of construction equipment and other necessary items.

After construction was completed, and maintenance and operation was begun, spare parts were procured for each of the sites, including sufficient restocking of spares for normal maintenance.

## ACCOUNTING

Accounting procedures were based on B&R's standard accounting policies, practices, and procedures. Separate, detailed ledgers and reports were maintained for each site. Except for the smaller sites, the account books were maintained at the sites, and depositories were established locally for the payment of subcontractors and

for local purchases. Where the books were maintained in the home office, the Project Accounting Group made payments from B&R's general depositories. All prepurchased material was paid for by the home office. When it was necessary to hire local personnel, payroll depositories were established in local banks, regardless of where the books were maintained. Regular accounting and financial reports were submitted by the field offices to the Project Accounting Group, including a monthly cost report. These were compiled into master reports and were submitted to W.E. and B&R's general accounting section. Periodic reviews of the field office accounts and ledgers were made by the Project Account Section.

## OPERATION AND MAINTENANCE

Burns and Roe was responsible for initial operation and maintenance of nonelectronic equipment at all sites except White Sands, Eglin, the two ships, and the Australian sites. Under the direction of a chief operating engineer, B&R tested the equipment and systems, and operated and maintained each station until relieved by an M&O contractor.

Actual contractual obligations by B&R varied greatly from site to site. At some sites B&R provided supervision only, at others it staffed the facility with locally hired help, and at Kano state-side operators were furnished.

In the early phases of operations, continuous difficulties were presented by the remoteness of some locations and the problem of obtaining supplies. Before B&R established replacement and spare parts stores, minor operational breakdowns presented major outages until replacements could be flown to the sites.

## PROVISIONAL ACCEPTANCE

Provisional acceptance teams were organized, consisting generally of two representatives each from NASA, W.E., and B&R. The primary function of these teams was the acceptance by W.E. and NASA of real and installed property, vendor and as-built drawings, residual construction materials, tools and test instruments, and test performance data of installed equipment. Rerun tests were made at the request of NASA and W.E. teams.

This data was compiled into three books:

**Book I Construction and Preurchased Specifications**

**Book II Shop Tests by Vendors**

**Book III Lists of:**

Real and Installed Property

Residual Material

Applicable Drawings

Contractor-Performed Tests

Field Operational Tests

Deficiencies

The acceptance was finalized by the signing of the above books by specified members of the teams. Deficiencies were corrected after the departure of the teams, and the books were corrected periodically.

## OPERATIONAL SPARE PARTS

Lists of operational spare parts and special tools for the diesel engines were submitted to W.E. for approval on April 1, 1960. Authorization to procure spare parts was received on June 20, and to procure tools on June 21, and orders were placed with suppliers. Lists of preoperational spare parts for the diesel engines were transmitted to W.E. on April 5 and May 9. These were approved April 12 and May 19, respectively, and were ordered from Allis-Chalmers.

In accordance with revised spare parts provisioning procedures, dated June 1, 1960, B&R provided W.E. with a proposed schedule of provisioning conferences to review spare parts requirements for equipment supplied by B&R.

A provisioning conference was held between representatives of W.E. and B&R on August 17-18, 1960. Immediately following this conference, preparation of multilith provisioning records began. These records were transmitted to W.E. between September 1 and October 27. A consolidated list of Group II common item spare parts was transmitted to W.E. August 6.

On October 14, W.E. requested order-of-magnitude procurement cost estimates. On October 18, detailed estimates were submitted for both peculiar and Group II common item spare parts. Authorizations to purchase these spares were received on November 4 and December 14.

In advance of receipt of purchase authorizations, B&R's Purchasing Department was requested to obtain quotations for spare parts on November 24. This procedure permitted issuance of all written purchase orders for authorized spare parts by December 20. Delivery of spare parts orders to W.E. staging areas was continually expedited until all items had been shipped.

## EQUIPMENT AND SYSTEMS MANUALS

The actual starting date for the preparation of equipment and systems manuals was May 6, 1960, when the first material was placed on order. Technical writers from B&R's Publications Department studied design drawings and specifications and began preparation of the system function and operation volume. All material was prepared at the level of comprehension specified for the project. Flow charts and schematics were analyzed.

Close liaison was maintained with Project Engineering and Construction so that design

changes and construction modifications could be incorporated shortly after they occurred.

Operating procedures were formulated for the component systems, and maintenance schedules in activities were suggested, with reference to the manufacturers' literature for details of individual items.

Illustrations consisting of photos, block diagrams, schematics, tables and suggested log forms were prepared and coordinated with the text.

The manufacturers' illustrations were separately tabbed, indexed, and bound. The entire set of manuals was uniformly bound in conformance with specifications.

Before publication, the manuals were reviewed by B&R's engineering divisions and by W.E. The first preliminary review copy of the systems manual was issued on May 16, 1960.

The final draft was issued on September 8. A total of 440 volumes was issued, covering equipment and systems and including a set of composite manuals for many of the sites that are somewhat similar.

## INTERNATIONAL BUSINESS MACHINES CORPORATION

The IBM Corporation was primarily responsible for performing the computer programming, and operating the computers at Bermuda and GSFC, as well as maintenance and operation of the launch and display data subsystems at Cape Canaveral.

## LAUNCH SUBSYSTEM DESIGN

### Systems Specification Development

As a result of a team study chairmaned by IBM starting in December 1959, a plan for the new Mercury launch subsystem was evolved. As a result of this work, a Phase II (Launch Monitor Subsystem Design and Equipment) contract was assigned to IBM in February 1960. The Launch Subsystem Design Specification has been published as Vol. I of MS-124, *Design — Launch Monitor Subsystem*. The design manual has been periodically revised to reflect changes introduced as a result of test operations and equipment problem solutions. Final revisions will be published as inserts prior to June 30, 1961. This

specification has served as the source document for all system implementation.

### System Problem Solutions

Throughout the development and test of the launch subsystem a continuous effort to identify and solve systems problems has been maintained. As systems problems were identified, a working group was assigned to the analysis and recommendation of solutions in terms of equipment, the operational program, and procedural changes where appropriate. It is anticipated that as a result of this activity, all outstanding systems problems will have been solved and a solution implemented by June 30, 1961. To date, 52 such systems problems have been identified and solutions determined.

## PROGRAMMING

The Mercury programming system has been compiled to include the processors and controls which enable the computations to automatically

proceed from launch-abort-re-entry or launch-orbit-re-entry and to process, in real time, a full set of Mercury data. This system has been undergoing rigorous testing and has been used to support the Mercury range tests and current launches. The system was used in the MA-3 launch, but has undergone a number of changes since that time. Retrofits were required for launches subsequent to MA-3 and were based on design specifications and changes based on experience with the Mercury system.

In summary, the Mercury computer system is probably the most sophisticated and powerful orbital tracking system in existence. It uses concepts which are at the height of the state of the computing art, briefly, as follows.

1. Results from the IP 709, Atlas guidance, and Bermuda computers are processed in a real-time mode by a centrally located computing facility at Goddard. These computers are linked by radio and high-speed transmission cables. The possibility exists for cross-talk between computers.
2. Two IBM 7090's at Goddard running in parallel and receiving inputs simultaneously. Outputs from either 7090 may be selected by manual control.
3. Radar network linked by a world-wide teletypewriter to the central computer. Position information goes to the computer and acquisition information goes back to the radar sites. This information can arrive simultaneously from many sites.
4. Displays at MCC driven in real-time from the Goddard 7090 via high-speed transmission (1000 bit/second) facilities. These displays include plotboards, wall maps, wall clocks, and various console displays.
5. Telemetry events can be manually overridden at Cape Canaveral, which cause alternate logical paths to be executed in the Goddard computers.
6. A highly sophisticated monitor program system handles all real-time interrupts, establishes priorities, logs all data, and controls the processing sequence. All are handled using multiprogramming concepts. Also, the program system is designed with the modular approach for complete flexibility in handling system changes.

7. Simulation procedures allow simulation of any flight with any sequence of telemetry events. This flight can be distorted by all types of errors which affect the system. This simulation can be done in real-time or in some multiple of real-time. Also, it is possible to use computer-generated data in real-time, using transmission facilities from Cape Canaveral and have the computers drive displays, again in real time. This technique and other variations are used for programming system testing and also for Cape Canaveral flight controller training.
8. The orbital system is completely automated in its use of observations and selection of solutions. One system automatically handles all phases of a flight, including launch, orbit, abort, and re-entry.
9. CADFISS is a technique which uses a computer to aid in establishing the operational readiness of the Mercury computational and data flow tracking system. This program-controlled technique is now a part of the Mercury countdown procedure.

### Goddard Orbital

#### *Input, Editing, Output, Orbit and Re-entry*

From August to December 1959, the basic structure of the data transmission equipment system and the formats of input and output data were established, and the planning of the basic computer logic for the real-time processing of the input and output data was completed. The programming of the processor of the low-speed radar data input began toward the end of this period.

The orbit and re-entry part of the Mercury computer system has consisted of development of the following programs:

1. A subroutinized numerical integration system with a fully checked out drag subroutine.
2. A subroutinized differential correction system with a substantial number of essential parameter testing capabilities.
3. A high-speed output system to feed displays at Cape Canaveral.
4. A program which computes the time to fire retrorockets to impact in a specified landing area and establishes the re-entry trajectory for a given time of retrofiring.

## 5. A real-time orbit and re-entry acquisition system.

The programming of the other input and output processor programs started in January 1960. By August 15, all processors needed for the initial system had been tested individually and incorporated in the system. Writeups for these routines were also completed at that time. System testing continued with simulation. A few errors were found and corrected. During this period, the programming was expanded to include the launch monitor subsystem.

A new method for editing the low-speed radar data was devised at the beginning of 1960. The coding of the initial method was completed by May. After many test runs, an improvement was made in the curve subdivision portion of the method. Another improvement was consequently made in the time sequence check. The discontinuity of the azimuth data was also taken care of.

When the DCC and the data transmission equipments were installed and checked out in November, both at Goddard and Bermuda, full-scale system testing began with live data, while simulation runs continued. Experience with various teletypewriter equipments and deeper knowledge of high-speed retransmitter buffer were very helpful in re-evaluating and reassuring the adequacy of the logics programmed. All input and output processors proved to function properly. Of course, there have been many minor specification changes which required frequent modifications to the existing processors and their writeups.

The high-speed output processor for plotting differential correction residuals at Goddard was individually tested and its writeup was completed in December 1960. Its incorporation in the system, however, has been postponed. Instead, the Goddard plotboard has been used so far to duplicate the plotboard displays sent to MCC.

In April 1961, the first version of the local vertical and refraction corrections were added. Ever since the first station characteristics tape was created in the summer of 1960, it has been updated many times with various modifications and additions to the updating program. The input formats of certain characteristics changed and some new characteristics were added from time to time. A considerable amount of changes in the geodetic data is expected when the new

Government data replace the data based on the present Mercury ellipsoid.

These programs have been coded, debugged, fully documented, and individually and system-tested with specially prepared test data. These tests have proven to be highly successful. The major area of concentration for the rest of the project will be the continued refinement of these programs in the Mercury system.

### Monitor

The monitor system was begun in August and outlined completely by December 1959. The priority system, use of indicators, operation of the save and return routines, the use of disabling and enabling programs, methods of taking advantage of the inhibited mode, timing and storage restrictions to be imposed on various kinds of processors, and means of queuing data were all defined and coded as the system began.

By January 1960, the main controllers were written and tested. Since then, the monitor system has only been modified very slightly in the coding, and not at all in concept. Parameters were used whenever possible so that numbers could be changed readily without changing the code. Since no real-time equipment was available, testing was accomplished by using random number generators to simulate traps until a clock was built to provide equipment interrupts.

When a partially completed DCC became available at the IBM Kingston, N.Y., plant in March 1960, the programs were tested there. Monitor programmers worked closely with design engineers and recommended changes in the operation of the hardware. A manual was produced on the DCC in February 1960 which was the only written material available on the DCC for almost a year and was used by engineers and programmers.

Once the DCC, the core of the equipment, had been designed and programmed, Channel A and B transmission was defined, and the on-line message system and logging routines were written. More than 20 trap processors, 6 subroutines, 22 monitor ordinary processors, and 40 prefixes and suffixes were written into the system. In addition, external routines were written to print logging output, to handle automatic dumping, to eliminate card handling by SOS, to generate required input tapes, and to diagnose new equipment. Pre-

fixes and suffixes have undergone constant change as the requirements of the system have changed. Since these are the routines which determine the interaction of the computational programs, every time a phase has been created or a new sequence of ordinary processors is called for, monitor logic must be written or amended.

In January 1961, once the system was operating near normally, the problems of interphase became pressing and two systems—one for launch and one for orbit-re-entry—had to be combined. The problems imposed by changing from one phase to the other were complicated by problems of operating in real-time, and also by SOS and core limitations.

The monitor shares importance as one of the major accomplishments of the whole Mercury program—that of having programmed a working system in the face of constantly changing requirements without sufficient test data and virtually no conclusive way to determine whether output is correct.

The most significant accomplishment of the monitor program work has been to take the broad specifications on the aims of the system and designs for unbuilt equipment, and produce a system which gives reliability and efficiency in handling the Mercury task as defined today, with enough builtin flexibility to handle changes which may arise tomorrow.

### *Simulation*

The simulation efforts have covered the broad requirements of nonreal-time and real-time simulation procedures. The procedures have enabled IBM to check out the programming system and to provide a means of training the MCC and Bermuda flight controllers and site personnel, and to operate the computing system under simulated launch-orbit-re-entry conditions. The latter function was an additional task not included in the original specifications. The simulation staff has developed a number of procedures to accomplish its mission.

1. Completion of a routine to simulate the DCC. This routine has been the primary debugging tool for the Mercury computer programs.
2. Completion of the set of routines to generate input for use with the DCC simulation.

Since July 1960, IBM has been modifying routines to incorporate new and changing input requirements. Some of these are:

1. Changes—
  - a. Radar formats;
  - b. Telemetry formats;
  - c. Specifications for GE/Burroughs and IP 709 formats;
  - d. STL data to permit aborts;
  - e. Profile program to incorporate changes in the mathematical model of orbit and re-entry and/or to incorporate new information about station parameters;
2. Real-time simulation runs—
  - a. Simulated IP 709 outputs for input to B simulation programs;
  - b. Simulated high-speed raw radar outputs for input to program which makes a tape used at the radar station;
  - c. Simulated low-speed radar outputs for use in producing low-speed teletype-writer paper tapes.

The five basic real-time simulation programs were checked out late in 1960 and are running. They are the closed-loop simulation for Goddard, the open-loop simulation for Goddard, the high-speed raw radar simulation program for Goddard, the Bermuda closed-loop simulation, and the Bermuda open-loop simulation.

A basic set of closed-loop tapes for Goddard and Bermuda has been generated from the STL data. A set of raw radar data tapes for Goddard has also been produced.

Several programs have been written which generate test pattern tapes for the B simulator. These tapes are used for testing the B simulator and transmission system between Cape Canaveral and Goddard.

To aid in the analysis of test runs, several programs have been completed which can print the data received by the computer. These programs decode GE/Burroughs data, IP 709 data, and raw radar data.

### *Standards*

The final SOS library tapes, decks, and listings have been completed, tested, and have been put in use, both at Goddard and Bermuda. The above

material, together with a complete writeup explaining how to create an SOS library tape and how to modify the SOS system tape to handle it, have been turned over to the NASA share librarian.

#### *Launch*

On January 28, 1960, W.E. authorized IBM to proceed with the launch programming.

By June 1960 the specifications for the launch programs were completed except for some details in the re-entry phase and the treatment of raw radar data.

The final launch system enables the computing system to accomplish the following tasks:

1. Process of high-speed data from the Burroughs computer, IP 709 computer, and the Cape Canaveral complex radars;
2. Low-, medium-, and high-abort techniques;
3. Compute and transmit a GO-NOGO recommendation and associated velocity and gamma information and the editing of data which enters into the GO-NOGO recommendation;
4. Sending of acquisition data to Bermuda;
5. Generation of a complete set of launch display quantities for MCC;
6. Analysis of telemetry data, with suitable error checks;
7. Recommendation of orbital capability;
8. Computation of retrofire times.

The work was continued from January to June 1961 and the programs were then delivered.

The postflight reporter program additional scope, supplies in report form a chronological history determined from the log tapes of a Mercury run. Four main subdivisions include log tape processors, mission phase processors, and monitor and utility routines. Since initiating, IBM has written, debugged, and tested some 30 subprograms involved in the postflight reporter. Documentation of some 20 of these has begun. Three subprograms remain to be completed before full-scale system checkout is possible. The period in May will feature cleanup of this first version together with its documentation. Postflight reporter will be involved in test runs at this time. Further, abort phase-re-entry displays presently omitted from the program will be treated. At a

time that raw radar data can be handled, this program will incorporate this feature.

#### *Bermuda*

The Bermuda phase, according to original planning, was to be a minimum system performing certain backup calculations to the Goddard system during the critical period of SECO to SECO plus 30 seconds when the capsule would be in a position to fire retrorockets. The primary calculations were to be a GO-NOGO determination and, if NOGO, to determine the time to fire retros to land in an acceptable recovery area. The basic tools were an IBM 709-8K computer with 0.1 second radar inputs from two radars plus certain telemetry information. Very little else was defined as to auxiliary computations or methods except that if time and space permitted such calculations would be made.

Work progressed very slowly at first due primarily to lack of definition in the areas of equipment, formats, inputs, and outputs. With the definition of the Goddard launch system, much of Bermuda was also defined as a byproduct. Much of this was in November 1959.

Program planning now progressed rapidly in the development of input, editing, smoothing, orbit determination, and output programs compatible with the stringent time and space requirements. In March of 1960 it became evident that computer space was insufficient for the programs planned and that either much must be cut out or a larger IBM 709 memory must be used. The larger-sized memory was obtained, and planning continued with time as the only limiting factor.

The computer was delivered, and in July 1960 the task of assembling the various program components with the monitor system was initiated. Considerable difficulty was encountered in these early days, particularly in the monitor, simulation, and input areas. The skeleton was completed by September 1960, making system testing possible of the over-all system.

By December 1960 the foundation was considered secure and so-called retrofit items or refinements began to be added. The logic necessary to handle unusual circumstances was continually being added as severe testing procedures made the need evident. Unsimulated testing by the closed-loop system was much delayed in getting started by unanticipated problems so that it wasn't until

the early part of 1961 that a successful run could be made and even then there seemed to be much to be desired.

An intensive effort was made to ensure readiness for the MA-3 shot. Extensive testing and correcting or strengthening of weak areas has been carried on for the last two months. All indications are that the Bermuda system will perform with a high degree of effectiveness during all possible phases of launch, orbit, abort, and re-entry.

Following MA-3, the effort continued to be one of refinement and systematic testing. The only major change is the addition of a numerical integration program to find a better impact point prediction in case of an abort in the Bermuda area. Some refinement of the sliding-wire method of determining impact point will be added following a research effort presently being made. In addition, changes will include procedures for three-orbit pass, boresight and local vertical corrections, and a procedure for determining the computation of capsule separation to prevent computing early SECO because of bad data. By June 1, 1961, the final system should be closed or completed. Of course, as a dynamic system it will always be changing gradually as better techniques are devised or requirements are revised.

## SPECIAL EQUIPMENT

During January-June 1960, special equipment was ordered as a part of the orbit phase and the launch phase. All equipment engineering and interface specifications were prepared and the subcontracts were placed. Design activity started March 1, 1960.

During July-September 1960 the following activities took place. Floor plans for Bermuda, Cape Canaveral, and SCC were made firm. Manpower was obtained for the installation phase and was assigned for training at Milgo Corporation. Installation and maintenance tools were purchased. A failure documentation and report system was initiated. Purchase orders were placed with the approval of W.E. for the site test equipment. The telemetry/event buffer for the launch subsystem was shipped to Cape Canaveral from Bendix Pacific and the output status console was shipped to Bermuda by IBM. Installation plans were made firm for all areas, including GSFC.

The trajectory simulator engineering specification was completed and work started on its design. A purchase order was placed with Milgo for the A recorder-reproducer for MCC. The telemetry/event buffer was installed and unit-tested at Cape Canaveral. The output status consoles for Bermuda and Goddard were installed and unit-tested. The Goddard console was installed at SCC. The switch unit, digital junction box, interface junction box, and data quality monitor and console were installed and unit-tested at MCC.

During the same period, initial IBM equipment manuals were shipped to W.E. and the necessary spare parts were shipped to cover the installation and test phase. Milgo encountered a problem in meeting specific schedules. To assist, IBM assigned three men full time at the Milgo location. Tools and test equipment for the sites were shipped to the respective sites.

All the equipment being supplied by Milgo was shipped to the respective sites. The trajectory simulator was delivered and installed at Cape Canaveral by IBM.

During October-December 1960, the retrofit to cover the telemetry/event buffer modification was installed at Cape Canaveral. All equipment supplied by Milgo, under contract at this time, was installed and was unit- and interface-tested. The second set of D/A and plotter was received, installed, and unit-tested at GSFC. This completed the IBM purchase orders with Milgo. The launch subsystem equipment installed at SCC on an interim basis was moved to GSFC where it was reinstalled and unit-tested. The high-speed loop test adapter was delivered and installed at GSFC in conjunction with the high-speed receivers and transmitters. All cables required for the installation of the launch subsystem equipment with the duplex 7090's were shipped and partially installed at Goddard. In this period, IBM was assigned responsibility for maintenance and operation of the computer programs through June 1961.

During the same period, the launch subsystem equipment at MCC was completely installed and unit-tested. The equipment at Goddard was also installed and unit-tested. Three tape recorders were ordered and shipped from Milgo. Installation was completed at Goddard, in the IP 709 building, and in the GE/Burroughs building.

Spare parts were ordered and all spare part listings were submitted on a preliminary basis to

W.E. All unit test data were sent to W.E. for review. Provisional inventory and acceptances of equipment was conducted at Cape Canaveral with no problem. First distribution of equipment manuals was accomplished.

During January-June 1961, all unit test specifications were again reviewed by IBM personnel at the site location and resubmitted to W.E. for publication and distribution. Submission of final spare parts listings was accomplished. The physical inventory of the equipment at Bermuda was accomplished for provisional acceptance by W.E. The second shipment of equipment manuals was completed. In February, equipment manual distribution was completed in accordance with W.E. requirements. Contractual coverage was received, purchase orders placed, and schedules developed to firmly establish delivery dates for peculiar spare parts. By April 1961, equipments functioned extremely well. A decision was made to install a frequency meter and variable oscillator in the trajectory simulator to obtain exact speed control. This equipment was installed by May 8, 1961.

Complete trajectory simulator retrofit modification, which allows for precise speed control, was also accomplished. An engineering change was initiated to delete the busy bit generator circuitry in the telemetry operation of the output message. This will allow generation of radar tapes for Bermuda. Peculiar spare part kits, final listings and decks of cards were submitted to W.E. All spare parts kits were shipped to the respective sites for equipment supplied. Inventory and provisional acceptance was accomplished for equipment supplied to GSFC. Projected revisions to equipment manuals requiring modification were accomplished. Safety changes required on equipment were installed to agree with IBM safety requirements. Engineering changes initiated were completed and installed by site personnel. Equipment and interface specifications were released to GSFC.

## TESTING

### Launch Subsystem

The launch subsystem test series was developed and implemented to test the operating features and equipment performance of the subsystem.

These tests were not concerned with the levels of accuracy nor the timeliness of data since this responsibility has been retained by NASA. The test descriptions and procedures for conducting the tests have been published in Vol. 3 of MS-124, *Testing—Launch Monitor Subsystem*.

The following test exercises have been developed and run. All of these routines have been checked for accuracy and may be presumed to be free of programming errors.

1. Raw Radar High-Speed Teletypewriter Program.  
(Simplex Test #1) The ability to run this test exercise from recorded radar data has not been proven. However, it has been accomplished with direct use of the radars in real time.
2. IP709 High-Speed Input Program.  
(Simplex Test #2)
3. Telemetry High-Speed Input Program.  
(Simplex Test #3) The variable portion of test 3B1 has not been accomplished as of this time.
4. GE/Burroughs High-Speed Input Program.  
(Simplex Test #4)
5. High-Speed Output Program.  
(Simplex Test #5)
6. Simultaneous High-Speed Program.  
(Simplex Test #6)
7. Teletypewriter Input-Output Program.  
(Simplex Test #7)
8. Output Status Console Program.  
(Simplex Test #8)
9. Clock Routine.  
(Simplex Test #9)
10. Maximum Data Flow Program.
11. Recorded Raw Radar Program.
12. Substitute for CADFISS (Teletype Program).
13. Local Plotboards Border Program.
14. Bermuda Telemetry Program.
15. Bermuda Output Status Console Program.
16. Bermuda Clock Test Program.
17. Bermuda Teletypewriter Input and Output Program.
18. Bermuda High-Speed Output Program.
19. Bermuda High-Speed Input Program.
20. Mercury Data Link Program (GE/Burroughs at Cape Canaveral to GSFC).

21. Digital Displays at Mercury Control Center Program.
22. Wallops Station Acceptance Program (Radar from Wallops Station to GSFC).
23. Wallops Station Demonstration Program (Teletypewriter from Wallops Station to GSFC).
24. Diagnostic High-Speed Input Program.
25. Diagnostic Teletypewriter Input and Output Program.

#### Integrated Subsystem Testing—CADFISS

The intention of the CADFISS project is to test the flow of data on all communication lines tied into the computers at Goddard. The initial thoughts on the project were that the tests (and hence the programs) would consist of three parts:

1. One-at-a-time tests, wherein each subdivision communicating with the 7090's would be independently and thoroughly checked;
2. Roll-call tests, wherein a number of subsystems would be checked one after the other using abbreviated tests;
3. Simulated flight tests, wherein the operational tracking programs would be checked using inputs and outputs extending as close to their true locations as possible.

As proceeded, two significant changes in attitude developed.

If a roll-call run was to be completed in any reasonable amount of time, the testing of the several subsystems (or sites) would need to take place simultaneously, and not in sequential fashion. Furthermore, whatever program was written to handle the roll call could just as easily handle a one-at-a-time test. And lastly, if several one-at-a-time tests were scheduled on the same evening, that IBM could save time by running them simultaneously. In other words, the difference between a roll-call test and a one-at-a-time test had all but vanished. IBM now has instead, the so-called short roll calls and long roll calls (or simultaneous one-at-a-time tests). The only difference between the two types of tests is in their size and composition — how comprehensive they are. But this is a program parameter and is not significant.

The second change dealt with the responsibility of the CADFISS programming team to the simu-

lation phase of testing. Since the CADFISS effort would have been almost an exact duplication of the efforts on the Mercury tracking program, IBM goals were considerably reduced. IBM was now to provide merely those programs which were essentially CADFISS oriented, but to leave to others the management and performance of simulation runs. This effort was extended.

The programs that have been written to meet these modified requirements follow.

1. *The CADFISS executive routine.* This program was developed to permit a simpler operational procedure when running roll-calls. It allows the operator to select by switches any of the several programs used in support of the roll call.
2. *CADMON, the real-time program used in roll calls.* CADMON sends cues (i.e. requests for data) to Mercury sites, and evaluates the responses received. The teletypewriter data evaluated consists of message patterns, radar boresight and range target data, and radar data from pointings in several critical directions. In addition, the program sends high-speed message patterns to MCC and receives and evaluates similar data originating at GE/Burroughs and IP 709 computers. Finally, it evaluates high-speed boresight data from the range radars.

Periodic on-line prints provide an up-to-date summary of the status of the tests. In addition, error data is written on magnetic tape for later analysis. CADMON has been successfully used with all sites communicating with the Goddard computers.

3. *The INPUT GENERATOR.* This program was written to simplify the problems in changing the configuration of a CADMON run. It accepts as input nonredundant information regarding the desired configuration (e.g., sites, circuits, and test types), edits this data for errors, and expands correct data into the several tables needed by CADMON.
4. *CABDA, the Bermuda 709 program used in support of CADMON exercises.* Under sense switch control, this program accepts high-speed data from either of the two Bermuda radars, extracts those reports made every sixth second, and transmits the extracted data to the

Goddard computers on the smooth-radar circuits. Another option allows teletypewriter data to be read from a Bermuda ASR into the Bermuda 709 and thence be transmitted to the Goddard computers.

5. *The HISTORY ANALYSIS program*. Following a CADMON run, this program sorts, analyzes, and summarizes the errors found during the real-time run. For example, it compares retransmissions of radar data with the original transmissions to permit an evaluation of the source of an error in a radar report: Was it the radar or was it communications?
6. *The paper-tape generator*. A program written for the CDC-160, which accepts simulated radar data on magnetic tape, and punches this data on paper tape for transmittal to radar sites.
7. *MXHSIC, MXHSPR, and MXHSPL*. The general rule adopted in support of simulation runs is that data received by the computers is to be checked by the computers; data received by the sites is to be checked by the sites. It is only in the case of high-speed data that any programs are necessary. The first of the programs named compares all received high-speed data against expected data. The second and third prepare *predictions* of high-speed data to be sent to the sites, both plots and samples of digital output. The sites (Canaveral and Bermuda) can then manually compare incoming data against the predictions as they are being received and report discrepancies. The standard for comparison in both cases is data derived from an in-house simulation run using SIC.
8. *Bermuda telemetry program*. A program used in the Bermuda 709 to evaluate the quality of dynamic telemetry data.

## SYSTEMS AND PROGRAMMING MANUAL DOCUMENTATION

### Systems Manuals

1. *Design* (MS-124, Vol. I). Completed and distributed.
2. *Operations* (MS-124, Vol. II). Concurrent with the final development of the systems specification, work was initiated on an operational description of the system and the specification of operating procedures. This involved a study

of the system specification in relation to the interactions within the subsystem and between the subsystem and other portions of Project Mercury. This effort has resulted in a description of the launch subsystem in terms of the following aspects:

- a. Functions and use of the subsystem;
- b. Operational use description of each unit;
- c. Procedures for control of the subsystem;
- d. A detailed chronological sequence of events and procedures occurring during a Mercury mission.

These descriptions have been published in Vol. II of MS-124, *Operation—Launch Monitor Subsystem*. This manual has been revised to reflect changes in the launch subsystem specification. A detailed chronological sequence of events required as support during a mission countdown has been completed. This document will be issued as a supplement to the operator's manual prior to June 30.

3. *Testing* (MS-124, Vol. III). Completed and distributed.

### Programming Manuals

All manuals will be ready for publication by June 1, 1960.

## CADFIISS MANUALS AND TESTING

By February 1961, initial issues of all CADFIISS manuals were distributed. Manual revisions and computer program modifications were necessary after final data was received. Representatives of IBM visited Langley Field on February 2 and described the activity of CADFIISS tests to NASA, W.E., and BTL. Due to delay in site completion dates, W.E. requested cost quotes for CADFIISS extension through June 30, 1961, to complete all sites.

The one-at-a-time test with Grand Canary was conducted and considered satisfactory. The one-at-a-time test for CADFIISS was one to three weeks behind schedule. Shakedown tests were performed at Cape Canaveral and GSFC and a roll-call simulated flight test was run without the complete facilities of Cape Canaveral and was successful through the launch phase.

In April 1961, the CADFIISS Engineering Group supported network drills and tests. The

CADFISS roll-call program demonstrated its value as a part of an operational countdown. This test provided an abbreviated and fast evaluation of the computer related data flow system and provided the ability to quickly recheck selected stations and equipment.

Check routines of high-speed radar, telemetry, and computer data to the Goddard computer simultaneously with checkout of teletypewriter inputs will be integrated in the high-speed input programs.

Addition of Verlort and FPS-16 slew checks via teletypewriter and high-speed inputs into the

Goddard computer will be added as part of the roll-call program. Distribution of teletype test tapes and test materials for CADFISS 1, 2, and 3 simulated flights to Group 2 will be made in May.

Distribution shipment of final CADFISS manuals has been completed. Rerun and final testing of all CADFISS tests with latest information available including revisions of final surveyed boresight and range target will be accomplished. Final checkout of programs for summarizing simulated flight test results will be completed, as well as final summarization of all test results.

### III

## STATION IMPLEMENTATION

This section discusses implementation highlights at each of the Project Mercury tracking and ground instrumentation stations from their inception through May 31, 1961. Major equipment systems installed at each site are reflected in Table I. The Mercury Control Center at Cape Canaveral is the focal point of the entire operation. The primary functions of MCC are to:

1. Direct the entire flight in respect to the mission;
2. Monitor the flight in respect to aeromedical and capsule systems;
3. Keep the astronaut and range stations informed of mission progress;
4. Coordinate all of the range stations and maintain a smooth flow of information to all of the units involved in the operation;
5. Supply information and alert the recovery forces following the decision to start re-entry.

In particular, MCC is responsible for assessing proper insertion of the capsule into its specific orbit and, normally, for deciding whether to abort the mission during powered flight. A station in Bermuda acts mainly as an extension of MCC and confirms that a proper insertion has been achieved. Bermuda may also be required to participate in the re-entry operation in case an abort is commanded by MCC or communications between Cape Canaveral and Bermuda are disrupted.

In addition to Cape Canaveral and Bermuda, there are 14 other network stations along the orbital paths around the earth. Twelve of these stations provide communications to the astronaut and telemetry reception during the mission. The remaining two, in the continental U.S., only provide tracking of the capsule during orbit and re-entry. A central computing and communications center at GSFC provides the required orbital and re-entry computing operations as well as the communications link between the remote stations and MCC.

These stations are manned by the following two groups. The flight controllers monitor the flight status of the capsule and over-all conduct of the mission, and advise and assist the astronaut in making decisions, as required. The flight controllers prepare a summary report at the completion of each pass for transmission to MCC. M&O personnel provide technical support in the operation of the various tracking, telemetry, and communications systems.

The following paragraphs summarize the implementation of the Mercury stations.

During initial project conferences, preliminary locations of acceptable sites were selected. Area determinations were based on the range capabilities of the radar equipment, characteristics of communications and tracking facilities, the planned orbital paths, and the necessity of maintaining contact with the capsule. Final, precise locations were established after thorough investigation by siting teams. Because of the global nature of the project, many sites were selected outside of the continental United States — Africa, Australia, Mexico, and islands in the Atlantic and Pacific oceans. Negotiations with the foreign governments involved were carried out by NASA, through the U.S. State Department.

Management teams, representing NASA, W.E., and B&R, visited certain foreign sites to pave the way for the siting teams. Local authorities were contacted and the objectives of Project Mercury were explained.

Siting teams were then assembled, consisting of engineers with experience in site development, logistics, electronic systems, design and construction. NASA, W.E., Bendix, and B&R staffed these teams, which were dispatched to the various sites to finalize locations and to collect all necessary information for detail design, construction, and operation. The data that these teams gathered provided fundamental design information in sufficient detail to minimize changes. Much information was collected — subsurface information, local

**TABLE I**  
**MAJOR SYSTEMS INSTALLED AND TESTED BY W.E. TEAM**

SITE LOCATION	RADAR	ACQ	TELE-METRY	COMMAND CONTROL	G/A VOICE RADIO	GROUND COMM	TIMING	SITE INTERCOM
CAPE CANAVERAL	●	●	●	●	●	●	●	●
GRAND BAHAMA	●	●	●		●	●	●	●
GRAND TURK	●	●	●		●	●	●	●
BERMUDA	●	●	●	●	●	●	●	●
ATLANTIC SHIP		●	●		●	●	●	●
GRAND CANARY	●	●	●		●	●	●	●
KANO		●	●		●	●	●	●
ZANZIBAR		●	●		●	●	●	●
INDIAN OCEAN SHIP		●	●		●	●	●	●
MUCHEA	●	●	●	●	●	●	●	●
WOOMERA	●	●	●		●	●	●	●
CANTON		●	●	●	●	●	●	●
KAUAI	●	●	●	●	●	●	●	●
POINT ARGUELLO	●	●	●	●	●	●	●	●
GUAYMAS	●	●	●	●	●	●	●	●
WHITE SANDS	●	●				●	●	●
CORPUS CHRISTI	●	●	●		●	●	●	●
EGLIN	●	●				●	●	●

facilities for transportation and handling of equipment, availability and practicability of local utilities (including transportation, housing, and medical facilities), availability of construction material, availability of local subcontractor organizations as construction labor forces, climate and meteorological information, and interference and line-of-site problems. During the siting trips, the teams arranged for all surveying required to locate the facilities in conformance with the actual topography, and in accordance with established criteria.

Qualified bidders were then selected for each location and were sent construction drawings and specifications and were requested to submit sealed bids. The successful bidder was determined after careful analysis.

Construction was then undertaken at each station in accordance with time-phased schedules. Existing buildings were adapted wherever possible to house the equipment. New structures were erected using local labor forces. Construction techniques varied according to available manpower and equipment availability.

At the completion of installation, unit and subsystem testing was undertaken using test procedures prepared by Team Members in the United States. These tests were conducted at the sites, and data sheets, indicating the results and recommended changes, were filled out at the sites and submitted for engineering analysis.

Following unit and subsystem testing, test aircraft were used to conduct dynamic testing at each station to verify the operation of ground equipment. These planes, supplied with electronic equipment, were flown over each site at a predetermined altitude, speed, and direction to simulate the path of an actual spacecraft.

This type of testing proved valuable in the correction of minor system deficiencies which were not readily identifiable by other tests.

Brief detailed and interference tests were also conducted to further verify station reliability for mission support. Provisional acceptance teams composed of representatives from NASA, B&R, Bendix, and W.E. then visited and accepted each site, pending the clearance of deficiencies noted.

Site completion dates for various activities are reflected in Table II.

At present, all sites are engaged in drills and

network tests to prepare for future Mercury missions and turnover of the network to NASA.

## CAPE CANAVERAL

The Cape Canaveral complex consists of the Mercury Control Center and associated facilities at Cape Canaveral, Grand Bahama Island, and Grand Turk Island.

The Mercury Control Center is housed in a building originally intended for telemetry receiving (TEL-3). This building required extensive modification and renovation to adapt it to Mercury requirements. Part of this work included the addition of a new wing to accommodate the Operations Room. During the course of installation and testing, numerous changes were incorporated into the intercom system to meet revised NASA requirements.

Responsibility for designing and providing equipment for the operations room was assigned to BTL. Stromberg-Carlson was selected by BTL to construct and install the consoles and displays for this area. Because of the rapidly changing concept of the MCC philosophy, it was not until February 1960 that reasonably complete requirements were available and agreements reached as to the specific instrumentation of these requirements. As a result of NASA's continuing study of the systems control problem, new NASA requirements were added to the installation work. Integration of these requirements was completed and tests were finished by the end of September.

A major effort at Cape Canaveral was writing the plan for the Mercury tracking and ground instrumentation system by the site implementation team. This document outlined the responsibilities of range personnel, NASA, and the Mercury Team Members at Cape Canaveral.

During the implementation phase, the support area functions in the MCC were revised. The changes, made at the request of NASA, integrated the Mercury operations more closely with the normal procedures at Cape Canaveral. On April 5, 1960, NASA authorized W.E. to proceed with implementation of communications facilities for recovery operations work at MCC. Implementation design for this work was completed on April 15, 1960.

**TABLE II**  
**SITE COMPLETION DATES**

<b>Sites</b>	<b>Survey</b>	<b>Construction</b>	<b>Installation</b>	<b>Installation Testing</b>	<b>Dynamic Test</b>	<b>Provisional Acceptance</b>
Cape Canaveral	8-16-59	5-1-60	8-17-60	10-22-60	10-22-60	12-16-60
Grand Bahama Is.	8-17-59	5-7-60	8-13-60	10-22-60	10-22-60	12-16-60
Grand Turk Is.	8-16-59	5-17-60	8-13-60	10-22-60	10-22-60	12-16-60
Bermuda	8-29-59	7-31-60	8-13-60	1-25-61	1-25-61	2-14-61
Atlantic Ship	10-29-59	8-25-60	11-5-61	1-20-61	1-20-61	2-25-61
Grand Canary Is.	9-28-59	7-25-60	10-7-60	12-31-60	12-17-60	1-31-61
Kano	10-30-59	12-31-60	2-23-61	3-31-61	5-13-61	3-9-61
Zanzibar	10-16-59	10-24-60	2-4-61	3-31-61	5-26-61	3-18-61
Indian Ocean Ship	10-20-59	7-29-60	10-10-60	4-28-61	3-24-61	4-3-61
Muchea	8-14-59	9-29-60	12-31-60	2-6-61	2-25-61	2-15-61
Woomera	8-16-59	10-1-60	12-17-60	2-23-61	3-16-61	2-15-61
Canton Is.	9-17-59	10-10-60	1-31-61	3-23-61	3-27-61	4-3-61
Kauai Is.	12-10-59	9-9-60	2-8-61	3-4-61	3-20-61	4-15-61
Point Arguello	12-17-59	9-26-60	1-25-61	3-22-61	5-3-61	5-12-61
Guaymas	3-1-60	10-13-60	1-25-61	3-3-61	3-3-61	3-11-61
White Sands	8-16-59	9-16-60	2-18-61	3-4-61	4-28-61	4-29-61
Corpus Christi	9-1-59	9-6-60	12-23-60	3-4-61	4-15-61	5-5-61
Eglin	1-10-60	9-16-60	1-14-61	3-16-61	5-24-61	5-27-61

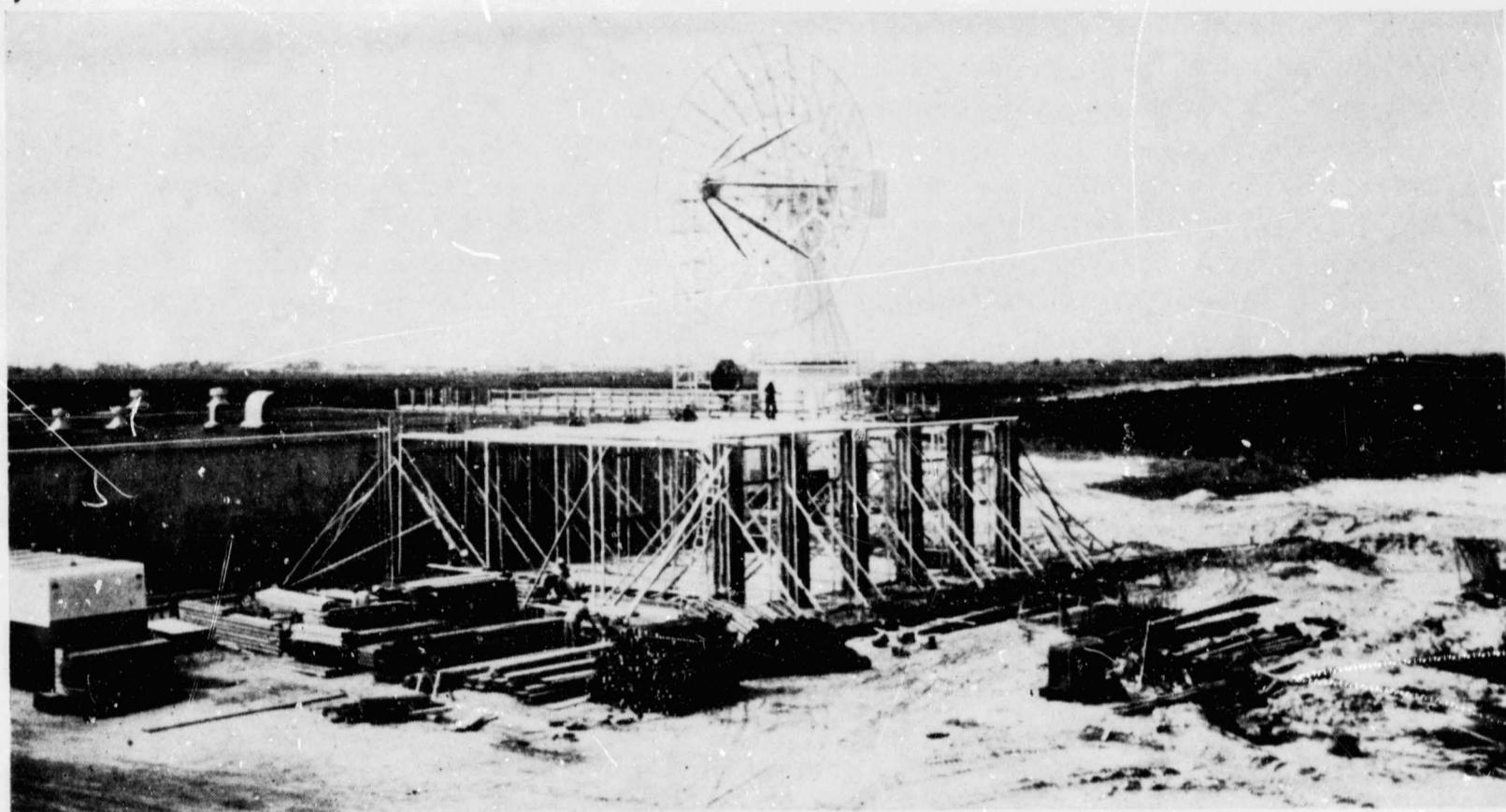
On July 20, 1960, W.E. requested AT&T Long Lines to proceed with provision of circuits and equipment required for the teletypewriter recovery network. In addition, AT&T Long Lines furnished the voice recovery telephone facilities and the high-speed data links to GSFC. Participation in Mercury Redstone and Mercury Atlas operations, simulation training, and considerable non-Mercury activity made it difficult to proceed on a normal schedule for completion of tests.

### BERMUDA

A site survey team visited Bermuda in August 1959 to select suitable locations for the construction of facilities. Sites were located within space presently allocated to the U.S. Government, one on Coopers Island, the other on the highest point on the island, Town Hill.

Completion of the necessary arrangement with appropriate authorities in November 1959, design of the facility began. This site, one of the most complex in the Mercury system, presented many problems, not the least of which was the inability to secure a construction subcontractor who would commit himself to meet the required completion schedule. As a result, B&R undertook construction with their own forces.

This site required more power (10-100 kw engines) than any other, more floor space in the T&C building (11,760 sq. ft.), more intrasite communications, and had certain inherent communications transmission problems due to reliance on radio for point-to-point communications. It is the only site that is required to procure fresh water by rainfall. It is also peculiar in that it is the only location where there are two widely separated telemetry and acquisition systems. (Town Hill



**Construction of the new wing to the Tel-3 building, Mercury Control Center.**

and Coopers Island are about 50 minutes apart by road and 6 miles by air.) This is the only site where a new FPS-16 radar (C-band) facility was constructed by the Mercury team. Construction was undertaken by B&R, and provision, installation and testing of equipment was accomplished by RCA.

Since it was among the earliest in construction, and represented the greatest majority of the systems at all sites, it became a testing ground for such items as the acquisition aid, the Verlort radar encoders, the compatibility with the FPS-16, etc. Findings at Bermuda were later incorporated into the design at other sites, if pertinent.

The IBM 709 computer was completely installed and tested prior to the start of training in early July. Stromberg-Carlson's installation crews began on-site activities in the Bermuda operations room in early June and completed most of the installation and wiring by mid-June 1960.

The W.E. team is performing M&O activities at this site under Letter Contract No. 2. This activity started on January 30, 1961.

#### **ATLANTIC AND INDIAN OCEAN SHIPS**

Two ships are being used as tracking stations. The Atlantic Ship, *Rose Knot*, will be stationed between Bermuda and Grand Canary Island and the Indian Ocean Ship, *Coastal Sentry*, midway between Zanzibar and Muchea, Australia. These ships were chosen during an October-November 1959 inspection of a group of C1-M-AVI class freighters that had been converted for tracking and pickup use on the Atlantic range.

During the remodeling period in the Mercury telemetry room, equipment was completely covered with a heavy plastic material. This material was sealed to the deck and to the adjacent sheets to make the enclosure dustproof. Interior heating units and air circulation was then provided together with wet-dry bulb thermometers to permit control of humidity within the equipment while the existing air-conditioning system was shut down and replaced.

Tests did not proceed according to original schedule because of revisions to certain unit and subsystem test specifications requiring further

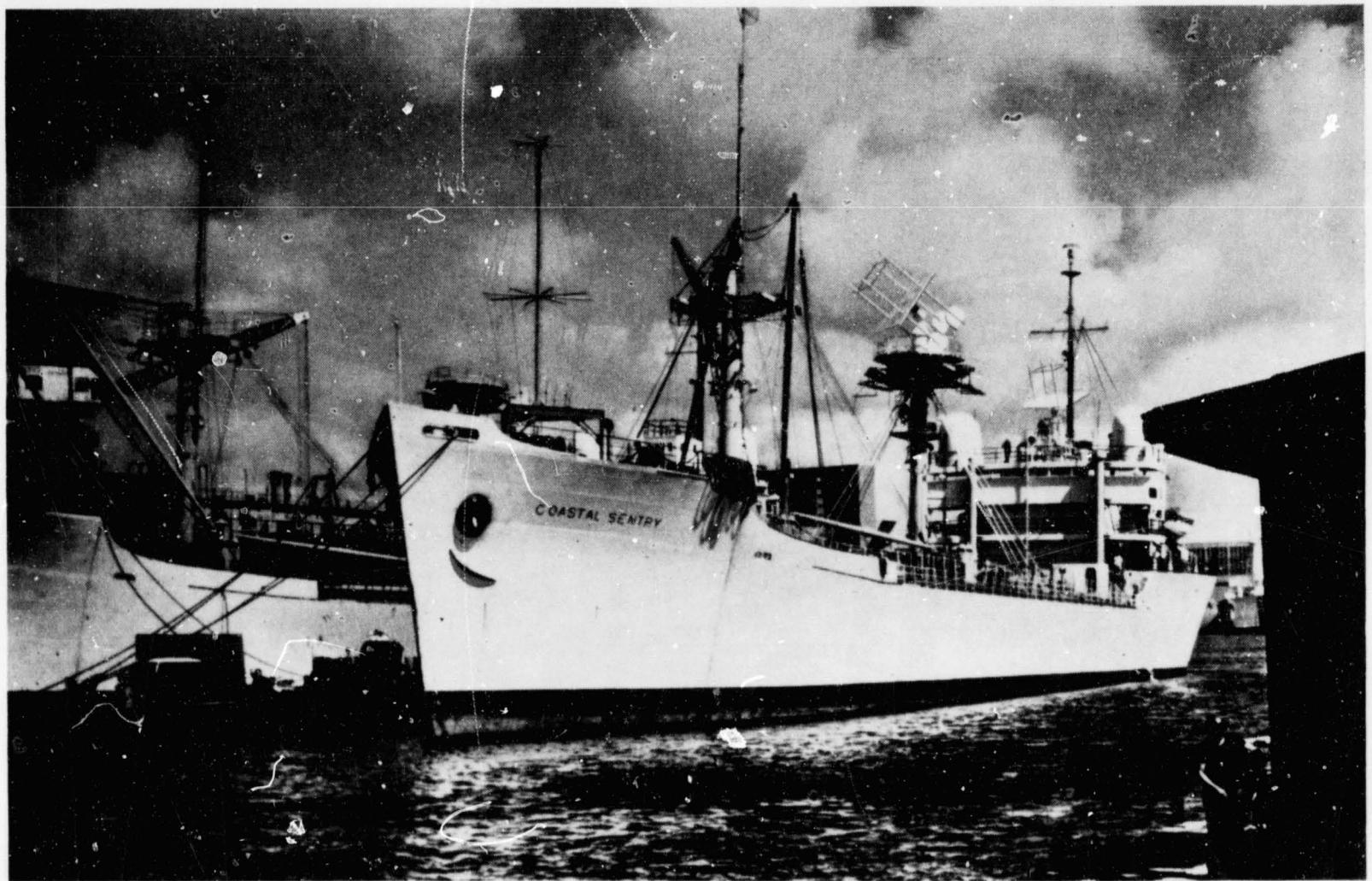
study and reaccomplishment of related tests and because of equipment failures, some of which were attributed to power generating equipment.

In October 1960, horizontal antennas were redesigned locally due to excessive weight of the end sections. During vibration studies at sea, it became evident that a vibration problem existed in the steerable antennas and in other equipment. These antennas were later removed and additional welding and bracing was accomplished. As a result of the data obtained and observations made during tests while on shakedown cruises, recommendations were made that resulted in several changes. The steerable antennas were redesigned to employ four round ground plane screens instead of one square one. Additional supports were added to the helices and HF dipoles and the position of the dipoles was changed. Stabilizers in the form of A frames were installed for the HF transmitters. Equipment was removed from the

port and starboard bulk heads in the telemetry room, and storage spares were provided for test equipment.

Following a series of impedance measurements, a complete new set of antenna matching networks and their enclosures were fabricated at Mayport for the point-to-point radio transmitting system. It was found that arcing caused considerable interference to the HF point-to-point receiving equipment aboard the ships. The arcing was caused by various stays, hatches, steel cables, chain-link railing, etc., which become excited by the HF transmitters. Considerable effort was devoted to the reduction of this arcing interference by bonding and removing interference sources from the ship. Arcing noise was reduced to a tolerable level; however, work is still continuing in an effort to further refine this problem.

During December 1960, it was discovered that the AFC units were not meeting capture-range



***The Indian Ocean Ship, Coastal Sentry, is one of the two ships used as Mercury tracking stations.***

requirements, which affected system performance at low signal levels. Modified AFC units were installed on the ships during April and May 1961, thus resolving this problem. Operating trouble developed in the control motor generator sets but the sets were replaced with a more suitable type which proved to be satisfactory.

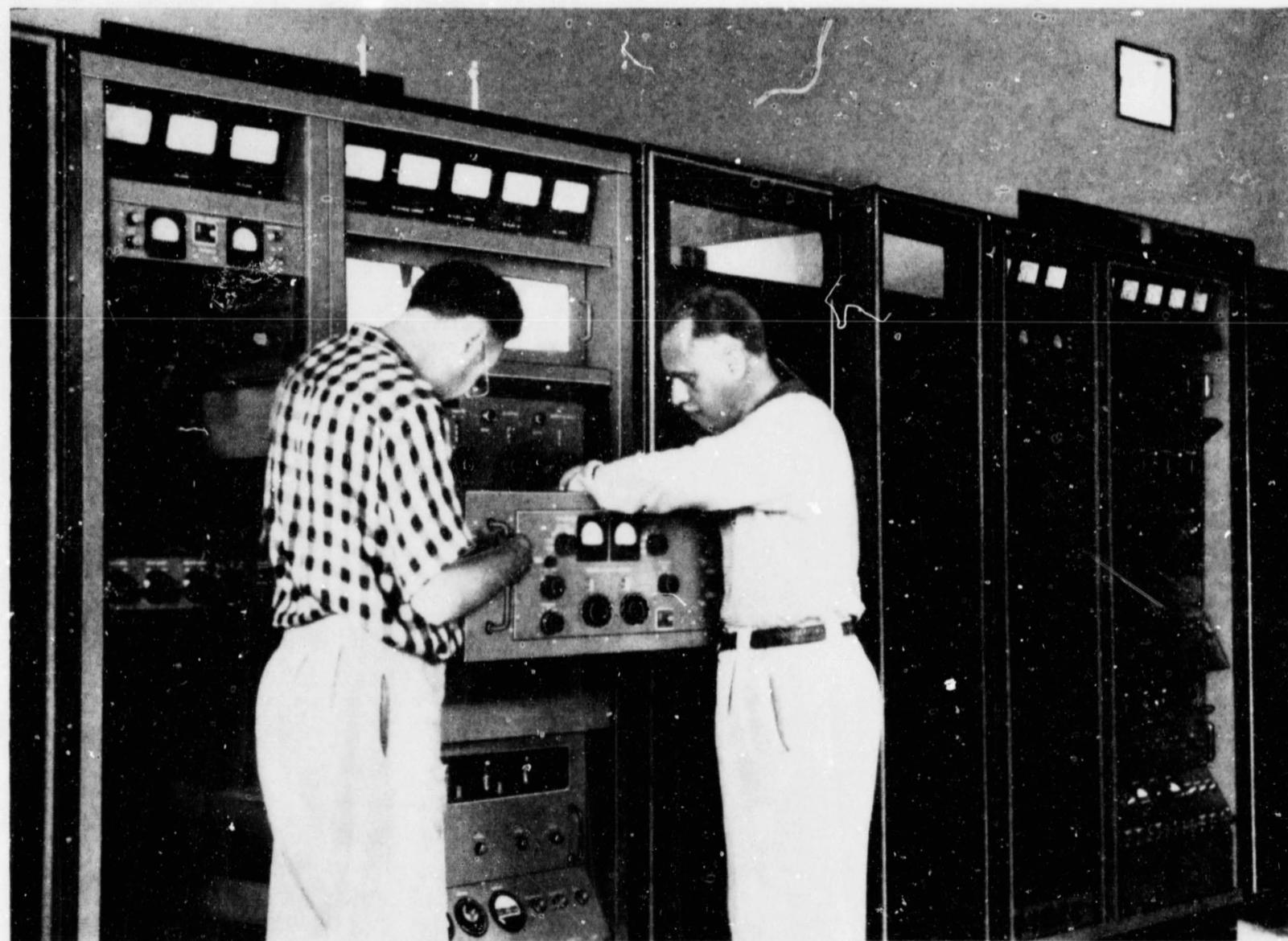
#### GRAND CANARY ISLAND

Grand Canary Island is approximately 30 miles in diameter and volcanic in origin, with mountains at the center and irregular slopes to the coast at all points. It is one of the Canary Islands, owned by Spain and located 120 miles west of the African coast, 28 miles north of the equator. It has a climate of approximately 80° mean temperature. NASA worked through the U.S. State De-

partment to obtain an agreement from Spain on the selected site. In order not to delay implementation of this site, Spain agreed that land acquisition, site construction, and the provision of ground communications by commercial carrier could proceed before the government-to-government agreement was signed.

The site is on the south side of the island approximately 40 winding miles from the largest city and only seaport, Las Palmas. Since the site is practically on the southern coastal plain, very little site preparation was required. Construction was under the joint supervision of W.E. and B&R representatives, but the entire labor force, including supervision, was composed of Spanish nationals.

This site also had its peculiarities, such as corrosive salt air which will corrode steel cables to



*Radio equipment installed at Transradio Español, Grand Canary Island.*

the point of uselessness within four months; a language barrier which caused a problem in interpreting American design drawings; and finding a suitable Spanish counterpart for specified items. The location of the site on the coastal plain was selected only after thorough evaluation of all aspects of a mountaintop site, since the latter afforded better look angles for the telemetry and tracking equipment. However, the roads to the mountain were narrow and winding, and construction costs so prohibitive, that the coastal site was finally used.

The communications for the site and its network tie-in were somewhat of a problem. The site is a key one for recovery operations and as a relay to the Atlantic Ship. Also, there are no network voice communications, and the teletype-writer network must be switched at London. Procedure variations between the commercial carriers at London and Grand Canary, plus the language barrier, caused some problems which required coordination.

Radio transmitting facilities were installed to provide communications between the station and the capsule recovery ship. New frequency assignments for the recovery transmitter were received from STG in April 1960 and these changes were filed with the chief of telecommunications in Madrid.

Letter Contract No. 2 covers M&O responsibilities. This activity started on December 19, 1960.

#### KANO, NIGERIA

The site is approximately 700 rail (550 air-line) miles from the seaport of Lagos and relatively near the Sahara Desert. The population density in and around Kano is second only to the Nile Delta. Farming is the primary occupation, thereby placing land at a premium. As a result, it was necessary to select available government-controlled tracts of land, properly spaced for the receiving and transmitting sites.

The transmitter area is located at the Nigerian Post and Telegraph's transmitter site, and the receiver area is at an abandoned landing field called the Dorayi strip. The transmitter area contains a transmitter building and its own power source consisting of a two-unit generator building. The receiver area contains a transmitter and control building, a receiver building, and a three-unit diesel generator building.

Early in the project a meeting was held with the Emir (native ruler) who granted permission for the use of the Dorayi strip. Local labor was used for the construction of the site. However, difficulties were experienced in obtaining qualified workmen, particularly electricians, and it was necessary to bring some experienced labor from Lagos to keep delays to a minimum. Unloading equipment was nonexistent at Lagos and the site equipment was unloaded from ships by manual labor in large numbers.

Dust storms are prevalent in this part of Africa during that portion of the year not classified as the rainy season, which extends from June through September. These conditions not only hindered construction activities, but created a continuing maintenance problem which was solved by limiting the outside air intake and conditioning the air in the buildings.

A problem of interest encountered during the construction phase was the necessity to make U.S. equipment compatible with European standards since American dies were not available locally.

A rather unique problem involved ants eating the sheath and pair insulation on the intersite cable between the T&C building and the radio transmitter site, some five miles apart. An investigation revealed severe damage at numerous points, and as a result a tape-armored, antproof cable was procured and installed as a replacement.

Maintenance and operations activities were assumed by the W.E. team under Letter Contract No. 2. This activity started on April 1, 1961.

#### ZANZIBAR

Zanzibar is an island in the Indian Ocean, lat. 6° 30' S, 12 miles off the African coast. This site was located on land controlled by the Zanzibar Department of Agriculture, with its full cooperation. The site is comprised of two separated locations necessary to provide Mercury-owned network communication. They consist of HF radio transmitters and receivers. The normal Mercury equipment and the HF radio network receivers with their power source of three 100-kw diesel engines are located in the Tunguu region, about 9 miles southeast of Zanzibar City. The HF transmitter site with its two 100-kw diesel engines is located in the Chwaka region, approximately 17 miles east of the city and about 6 air-line miles from the receiver site.



***Laborers digging trench for intersite cable at the T&C area, Kano.***

The construction problems here were minimized because the terrain was relatively flat with no hard rock. The site grading and roadwork was performed by the Department of Public Works under a subcontract from the Mercury team. Some few difficulties ensued from variations in bolt and pipe threading standards, since those used by the subcontractors were unlike American standards. The problem of connecting normal 50-cycle commercial power for 60-cycle operation was not encountered because the cost for a commercial power tie was prohibitive.

Since Zanzibar has no deep-water port, all surface shipments must be lightered ashore. This extra handling probably accounted for the comparatively high damage to equipment for the site. Also, heavy lifting equipment was not available and several heavy crates were dropped, causing some extra damage to the equipment.

Some delay was encountered because it was decided rather late in the project that a UHF radio link between the site and the city would be

used rather than a normal cable or open wire line. This link was strictly for local communications between the two sites and the Zanzibar central telephone office. In addition, this site required a radio link to the Indian Ocean Ship, which necessitated the erection of 90-foot LP antennas. This presented a problem which was solved by bringing a hoisting crane from the mainland.

A recent problem involved excess heat in the HF radio transmitter building, due largely because the outside air is hot and humid with normal temperatures up to 115° F and 120° F. The power was reduced with some lessening in transmission capability, but a permanent solution has been designed which involves adequate air-conditioning and filtering equipment to bring the building temperature down to 80° F under full power.

The site is currently being maintained and operated under Letter Contract Number 2. This activity began during April 1961.

## MUCHEA AND WOOMERA, AUSTRALIA

Two stations are in Australia. One is approximately 40 miles north of Perth near Muchea. The other is at D of S headquarters near Woomera, South Australia.

In accordance with an agreement between NASA, the Australian government, and W.E., all construction and installation work at these sites was accomplished by the Australian government. The implementation and operation of these stations is also under Australian direction. The W.E. team furnished technical criteria and design information, as well as technical advice and advisory personnel.

To finalize plans, contractual negotiations, and technical details for these stations, NASA and Team Member representatives visited Australia and met with personnel from D of S, the Department of Public Works, the Postmaster General's Department, and the Overseas Telecommunications Commission. As a result of these meetings, D of S provided construction schedules, approximately 90% of the site drawings, and about 70% of the detailed specifications. It was also agreed that D of S and the Postmaster General's Department would be responsible for internal site communications and that Overseas Telecommunications would provide external links.

At Muchea the electronic grounding did not meet Mercury criteria so the Department of Public Works engineered a new grounding system. Since the faulty grounding was a result of sandy earth conditions in the area, copper pipes were sunk 140 feet into the ground near the Mercury buildings and outside equipment, which enabled the critical limit to be met at both sites. The equipment drawings had to be explained to Australian trained technicians. This was a significant problem since symbols, spelling, and electronic terms vary considerably between the two countries. Since all commercial power in Australia is generated and transmitted at 50 cycles, it was necessary to make the 60-cycle Mercury equipment compatible by the use of frequency conversion equipment. The teletypewriter equipment was also provided by the W.E. team, even though some of it was located in the offices of commercial carriers. This was necessary to ensure homogeneity of the entire Mercury network, and simplify the spare parts and instruction problem.

A special problem area was encountered at Woomera due to scheduled range use (other than Mercury) of the FPS-16 radar. This caused delay in testing interconnections to it for Mercury equipment.

## CANTON ISLAND

Canton Island lies approximately halfway between Hawaii and Australia. The island is a small coral atoll at lat.  $2^{\circ} 47' S$  and long.  $171^{\circ} 40' W$ . It is under a codominion status with both British and U.S. commissioners having the FAA manager. The site is located in an isolated area five miles east of FAA facilities. Mercury facilities include a T & C building and a three-unit diesel generator building. Construction work at the site was done by a U.S. construction unit, working with Mercury team designs, drawings and supervision.

Considerable early coordination with various island agencies was necessary to procure housing, messing, vehicle usage, repair, and access to other island facilities. The telephone system had to be replaced with a larger unit to accommodate Mercury requirements. Also, the FAA agreed to act as a commercial carrier for network communications at both Canton Island and Honolulu, at which point it was channelled into regular commercial facilities. These radio facilities were furnished by Mercury, but installed by FAA at both points.

Transportation was and is a problem. There are no regularly scheduled ships of call, nor any regular airline schedule. Since the construction unit required a considerable amount of construction gear and material, the U.S. ship, *Frank T. Petrarca*, was used. Through expediting, the Mercury team was able to load a major portion of its power switchgear and air-conditioning equipment on this ship, which arrived at the island in May 1960. A later scheduled trip by the same ship carried a major portion of the electronic gear. All other shipments were made by air, either on a charter basis or a regular tariff basis.

The lack of any regularly scheduled airline stops resulted in very slow mail deliveries. Also, communications were somewhat limited until the additional radio facilities were installed.

Because Canton Island is a coral atoll, the salt air corrosion problem is ever present, so all exterior steel fixtures had to be specially treated. Also, there is no fresh water on the island; therefore, distillation equipment had to be provided.

## KAUAI ISLAND, HAWAII

The site is adjacent to the access road to Kokee State Park and comprises three separate locations; the T&C on Halemanu Peak (3750 feet high) overlooking Waimea Canyon (1250 feet deep), the Verlort radar location about one mile away, and the power location halfway between the two with the FPS-16 radar directly behind it but on higher ground. This site was selected after consideration of two proposed sites on Oahu, which could not be utilized due to economic and interference factors.

Commercial backup power and network communications were made available, but all intra-site cabling between the three locations along Kokee Road was designed and supervised by the Mercury team and installed jointly by the Department of Public Works Office of Honolulu and the Hawaiian Telephone Company under subcontract.

There was practically no skilled labor on the island. As a result, practically all the skilled tradesmen were imported, largely from Honolulu. Since the site was approximately 18 winding miles from the nearest living quarters, the vehicles suffered severe maintenance costs, but only one minor accident occurred.

The site suffered some delays due to late arrival of GFE equipment such as the command vans and the FPS-16 radar gear. However, the dynamic testing team was occupied there longer than any other site, due to the heavy rain and fog surrounding Halemanu Peak.

Considerable tree clearing was required for the roads and buildings. All this work, together with site grading was also performed by the Department of Public Works Office under a subcontract.

## POINT ARGUELLO, CALIFORNIA

This site is at Point Arguello in Southern California. It had been originally planned to locate this facility at Point Mugu, and this site

was surveyed. However, it was subsequently learned that existing facilities at Point Arguello could be better adapted for Mercury use. The Mercury equipment at Point Arguello is at five different areas. Area No. 1 is at the existing UHF building, Area No. 2 is at the existing telemetry building, and Area No. 3 is at the range operations building. Area No. 4, on Tranquillon Peak, includes an FPS-16 radar modified for Mercury use. Area No. 5 contains the S-band radar tower with its supporting facilities.

The government provided for road construction to the station and shared the cost of building construction. The existing Verlort radars were not available for Mercury, but NASA obtained an additional Verlort for installation. The command vans were also provided by NASA and some delay was encountered due to late delivery.

During the construction phase, close inspection of the concrete was required. Approximately 1½ hours were required to truck concrete from a plant in Lompoc to the top of Tranquillon Peak. Consequently the mixture was often partially set before arrival. Some had to be discarded prior to pouring, and the concrete for the acquisition aid tower foundation had to be removed and new concrete poured. The fact that the five areas were relatively widely spread and all involved modifications to existing buildings contributed to the difficulties.

Several days delay was experienced during the installation phase when a brush fire necessitated closing access roads to the site.

It was originally intended to use commercial communications equipment for the site facilities as well as network facilities. However, due to site conditions, it was necessary to provide NASA-Mercury-owned facilities for site use. These became a part of the existing government communications complex.

## GUAYMAS, MEXICO

The site is near Guaymas, on the shore of the Gulf of California.

Before site implementation could begin, extensive negotiations between the U.S. and Mexican governments were conducted to review the degree of their participation, availability of materials for construction in Mexico, special techniques of procurement, contracting and construction in Mexico, and the need for Spanish

translations of bid documents. Resolution of these matters delayed site surveys and subsequent implementation.

The construction contract was awarded to a licensed Mexican construction company. Some difficulties ensued because a detailed list had to be developed showing the various items to be procured in Mexico, as well as those to be procured in the U.S. and cleared through customs at Nogales, Arizona. A freight forwarder's representative and a W.E. man were resident in Nogales to attend to the customs clearances, as well as staging and transportation of equipment through Mexican territory.

Following a detailed inspection of the open wire lines in January 1961 by representatives of NASA, Telefonos de Mexico, W.E., and AT&T Long Lines, the wire line was repaired and adjustments and overall alignment of the C-carrier at the Guaymas and Nogales terminals and at the Hermosillo repeater point were made. The wire line continues to give some trouble because it is routed adjacent to a river bridge from which fishing is quite popular. However, this situation is now being cleared.

Care was exercised in the selection of W.E. and Team Member personnel at the site to ensure that bilingual personnel were selected. This was extended to embrace the concept that the Mercury site was a tenant in a neighboring country which could exercise landlord rights.

Another problem involved the provision of the commercial power tie for the site. The existing line not only did not extend to the site, but even as far as it did extend, the line was not physically capable of carrying the added site power requirement. Arrangements were made with the Federal Power Commission to reconstruct the existing line and extend it to the Mercury site where it will be used for all utility loads. The electronic load will be supplied by Mercury-designed and installed diesel engines and power systems.

#### WHITE SANDS, NEW MEXICO

This site is at the White Sands Range. Space was made available in existing buildings to house Project Mercury equipment. Use was made of the facilities and utilities existing at White Sands.

The C-area, comprising existing FPS-16 radar facilities, was chosen for the tracking station. It was first thought that the Organ Mountains to

the west might interfere with an early acquisition of the capsule. However, NASA determined that the azimuth angle did allow for an early acquisition. An existing building in the C-area was used to house equipment needed in conjunction with the existing FPS-16 radar. Construction work included the erection of antenna and boresight towers and modifications to the buildings.

An implementation team consisting of Bendix, B & R, NASA and W.E. representatives met with Government personnel at White Sands in March 1960 and reviewed the implementation plan for this site so that the exact location of all structures could be determined. Following this work, a revised siting report, fixing the locations of all buildings, was completed and reviewed by NASA and the W.E. team. The plan was approved by White Sands and NASA personnel.

The only real installation and testing problem encountered at this site involved the various interconnections between Mercury-supported equipment and the already existing equipment. It was necessary for RCA to modify the IRACQ/FPS-16 equipment and, since the equipment was being used for other range requirements, strict scheduling had to be employed.

#### CORPUS CHRISTI, TEXAS

After negotiations with GSA, the Mercury site in Corpus Christi was located at Rodd Field, a deactivated airfield. Following a visit by the site survey team, it was decided to modify an existing two-story hangar (No. 454) to accommodate the Mercury equipment. Antennas were erected on the hangar roof. The S-band radar tower and the ground-to-air transmitter facilities are near the hangar. Since the hangar was available, a minimum of construction work on the structure was necessary although modifications within the building were extensive.

The Southwestern Bell Telephone Company provided all leased communications to the site, including teletypewriter and PBX equipment. However, the intrasite communications facilities were designed, installed, and tested by the Mercury team. Local power and water companies constructed facilities for the Mercury installations.

Rodd field, because it had been deactivated and is under the jurisdiction of GSA, was partially dismembered by public sale after construc-

tion was in process. As a result, the area completely surrounding that portion of the field allocated to Mercury facilities was sold to various agencies, which required that the Mercury location be fenced off from the remainder of the land.

## EGLIN, FLORIDA

The Mercury equipment is housed in existing buildings, which required minor modifications. It is on flat, swampy ground approximately 47 miles northwest of Panama City and 10 miles north of Port St. Joe.

An implementation plan detailing design, construction, and logistics was written by representatives from W.E., NASA, B&R, Bendix and Eglin.

Since Eglin had available ground electronic equipment required for Project Mercury, the major facilities required were land lines to GSFC and to MCC.

The Government constructed an automatic telemetry tracking system for Mercury acquisition.

Some trouble was experienced with unstable power due to poor regulation. This situation was remedied.

Considerable coordination between Government and Team Members personnel was necessary at this location due to other range requirements affecting the availability of radar for interconnection and testing.

## GODDARD SPACE FLIGHT CENTER

The communications and computing center for the Mercury tracking and ground instrumentation system is at GSFC, Greenbelt, Md. Telephone, teletypewriter, and high-speed data information is controlled by GSFC. Prior to completion of GSFC, the communications and computing facilities were at SCC in Washington, D.C.

In October, 1959, a 709 computer was installed in place of the existing 704 computer at SCC. The new computer was used to check out programs for the system and was used at the Interim Communications and Computing Center. There were various interface problems between the teletypewriter and the IBM real-time channel. In May, NASA and W.E. representatives met in Washington and agreed to the final configuration

for the control position at GSFC. Final agreements were also reached on the floor location of the Mercury teletypewriter equipment at GSFC.

The real-time installation at SCC was delayed because the 709 computer was needed for tracking the TIROS, Transit, and Echo satellites. This delay pushed back the operational date for the SCC configuration, which used the real-time channel in connection with Demonstration Site tests, to June 25, 1960.

The design of the Goddard teletypewriter switching center was frozen in late June 1960. All schematic drawings involving material to be supplied by the telephone company were completed. NASA and the W.E. team met in July and decided to utilize the computers in checking the world-wide system. From agreements reached at the meeting, IBM developed detailed plans for a computer-related network test.

A series of meetings were held among the W.E. team to discuss problems of high-speed data transmission between GSFC and MCC. Trouble-reporting procedures were agreed to and the operating company set up arrangements for in-service checking of the performance of the data circuits. Teletypewriter network reliability studies proceeded. It was later agreed that tests would continue, with NASA sending results to BTL and W.E. Bell Telephone Laboratories studied the problem and initiated plans for future study and analysis.

Numerous hours of test data for the launch subsystem were accumulated on the reliability of the high-speed data lines in the direction of Cape Canaveral to GSFC. In addition, the launch subsystem performed satisfactorily during all MA and MR missions. Western Electric representatives at GSFC developed a proposal for recording and analyzing communication network difficulties.

As a result of NASA and W.E. Team Member investigations, a number of modifications and additions to the SCAMA board at GSFC were made:

- (1) adding station instruments,
- (2) changing all instruments to include push-to-talk feature,
- (3) adding key controlled bypass arrangements of two Cape Canaveral lines on the SCAMA board,
- (4) modifying the SCAMA board to allow multiple-talk communications on the conference lines,
- and (5) adding several key telephone line pickup arrangements at the IBM computer room telephone.

## DEMONSTRATION SITE

Wallops Island, Va., was selected as the field Demonstration Site. Its function was to test and demonstrate equipment and to train operator personnel assigned to the tracking stations. Mercury facilities were installed at two sites: one at the deactivated Chincoteague Station on the mainland and the other at Wallops Island in the existing FPS-16 radar building.

Dynamic tests at the Demonstration Site were postponed until July 1960 because the aircraft test equipment was not available for installation at Friendship International Airport, Maryland, until mid-May. In late April, NASA approved the retention of the ground and tracking instrumentation system equipment at the Demonstration Site rather than transfer this equipment to other Mercury stations. This allowed adequate time for tests and demonstration. Western Electric authorized Team Members to immediately in-

itiate a program to procure replacement equipment for sites that were scheduled to receive the demonstration equipment.

Early in January 1961, NASA, Bendix and W.E. representatives visited the site to inspect the procedures Bendix Radio used to mothball the Mercury equipment. On January 9, 1961, the site was temporarily reopened to support the testing of modifications to the McDonnell capsule elapsed time (CET) and time of retrofire (TORF) clocks using the NASA-231 plane. Closed-circuit TV tests were performed during the week ending January 13 in conjunction with the same plane. The test satisfactorily demonstrated the effectiveness of this equipment to expedite dynamic testing by providing a visual presentation of the tracking antenna performance during test flights. NASA authorized the purchase of three such systems, one for each aircraft to carry from site to site.

# APPENDIX

## LIST OF ABBREVIATIONS

AAA	—Active acquisition aid	MCC	—Mercury Control Center
AFC	—Automatic frequency control	MCO	—Mercury Change Order
AR	—Acquisition and receiving	MR	—Mercury Redstone
ATR	—Acceptance Test Requirement	NASA	—National Aeronautics and Space Administration
B&R	—Burns and Roe, Inc.	NBS	—National Bureau of Standards
BTL	—Bell Telephone Laboratories	PBX	—Private branch exchange
CADFISS	—Computation and data flow integrated subsystem	POE	—Port of Embarkation
C&E	—Communications and electronics	SAG	—Systems Analysis Group
CCN	—Contract Change Notification	SCAMA	—Switching conferencing and monitoring arrangements
DCC	—Data communications channel	SCC	—IBM Space Computing Center
D of S	—Department of Supply (Australia)	SECO	—Sustainer engine cutoff
FAA	—Federal Aviation Agency	SEG	—Systems Engineering Group
GFE	—Government-furnished equipment	SIC	—Simulator input control
GMT	—Greenwich Mean Time	SOS	—Share Operating System
GSA	—General Services Administration	STG	—Space Task Group
GSFC	—Goddard Space Flight Center	T&C	—Telemetry and Control
IRACQ	—Instrumented radar acquisition	VATS	—Voice, acquisition, and telemetry system
LP	—Log-periodic	Verlort	—Very long-range tracking
MA	—Mercury Atlas	W.E.	—Western Electric Company
M&O	—Maintenance and operation		